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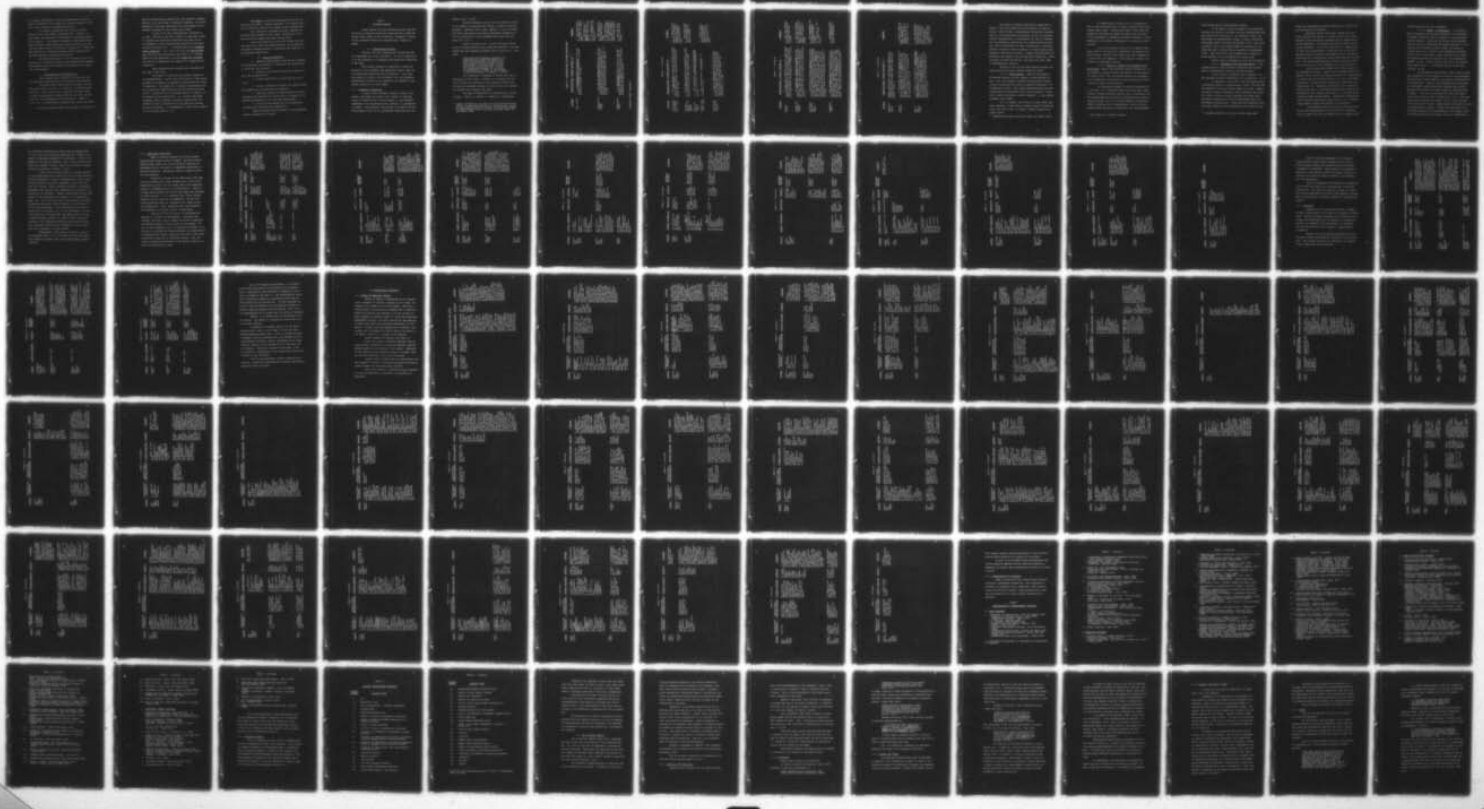

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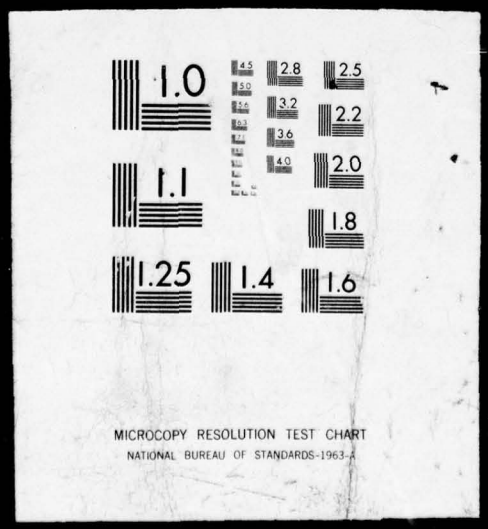

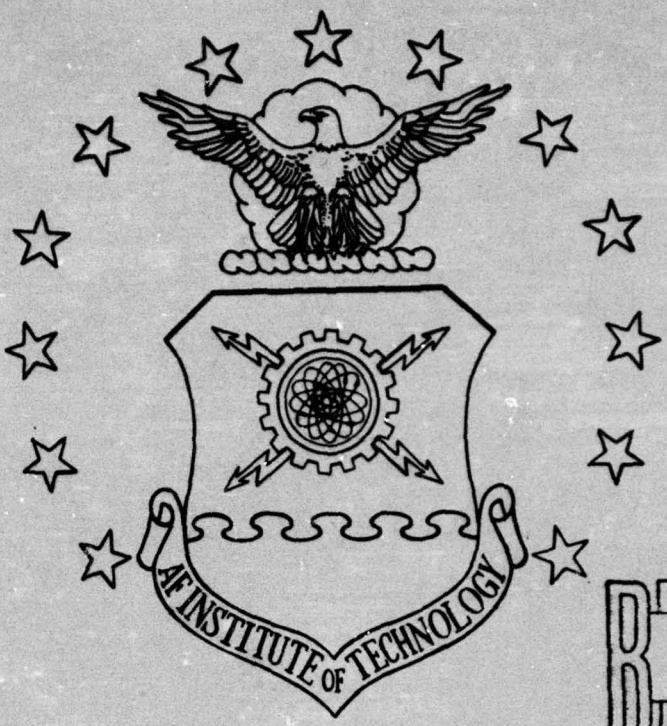

UNITED STATES AIR FORCE

AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

INNOVATION AND PRODUCTIVITY IN RESEARCH AND DEVELOPMENT: SOME ASSOCIATED INDIVIDUAL AND ORGANIZATIONAL VARIABLES

Technical Report

AFIT TR 76-10

Michael J. Stahl
Capt USAF

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ABSTRACT

This research explored the relationships of organizational variables and the innovation and productivity of scientists and engineers in Research and Development Laboratories.

Innovation and productivity were viewed as two separate dimensions of scientific/engineering output. Innovation was defined as output that is original and useful, whereas productivity was defined as quantity of output. Peer ratings of innovation and productivity, completed by other scientists/engineers within the same work group, were the criteria measures.

A list of organizational variables was developed from relevant empirical studies in the literature and tested for their relationships with the criteria.

The method included a questionnaire administered to the individual scientist/engineer that provided data for the peer ratings, and most of the organizational variables. Questionnaires from the group leaders and information from lab records provided data for some other organizational variables.

Usable information was obtained on 154 civilian and military scientists/engineers in 36 work groups in three Air Force R&D Laboratories. Analyses were performed at both the individual and group levels.

The peer ratings of innovation and productivity

were found to be of a reliable nature. Face validity of the criterion variables was implied by the distributions of the criterion scores, and by the finding that the productivity scores were significantly greater than the innovation scores. Innovation and productivity have a high positive relationship.

The following consistent relationships were found by analyzing zero order correlations, regressions and canonical correlations. Rewards for innovation is the variable most consistently related to innovation, and to productivity, and to the bivariate criteria, at both the individual and group levels. Frequency of communication with other scientists/engineers within the group on technical matters is positively related to innovation, and productivity, and the joint criteria at the individual level, as well as to innovation at the group level. Participation on goal setting and the group leader's empathy are both positively related to productivity at both levels of analyses. An age-education group of variables is significantly related to innovation, and to productivity, and to the joint criteria at the individual level.

PART 1

INTRODUCTION

1.1 Background

The question of organizational or situational determinants of innovative output in a Research and Development (R&D) Organization has only recently been empirically investigated. This is partly evidenced by the devotion of the first four University of Utah Research Conferences on Creativity, summarized in Taylor and Barron (1963) and Taylor (1964), to personal determinants of creativity and the criterion problem. Not until the seventh conference, Taylor (1972), did the conferences start to pay any attention to organizational factors. Indeed, even then, most of the work consisted of "theorizing" on "optimal climates for creativity."

Unfortunately, for the practicing R&D manager or interested scholar, most of the R&D management literature in this area is of a "cookbook" variety. Much of it consists of "how to do it" lists to help the R&D manager create/improve a climate for creativity. Most of the lists were based on "expert opinion" and little empirical evidence. For example, Orth (1959) wrote:

> "The creative work of research personnel is the basic product of the research laboratory and the degree of productivity evidenced by laboratory personnel will depend on the degree to which the optimum climate for professional research work has been developed and maintained by research management." (p.55) (Emphasis added.)

In a fashion replicated by many, Orth proceeded to propose a list of "elements of the climate for creative research" (p.58) with little evidence to substantiate the list.

The studies contained in the literature review section (2.2.1) were based on empirical data. However, in many cases, the definitions and measures of innovation employed are nebulous. Some measured innovation, some productivity, some creativity, some originality, some recognition, yet most used the common title of creativity or innovation.[1] There were also substantial differences between studies concerning how the organizational variables were measured.

The above deficiencies in the literature led to the problem that is explored, namely, what organizational variables are associated with the innovation and productivity of scientists and engineers.

1.2 The Problem and its Limitations

What organizational variables are associated with the innovation and productivity of scientists and engineers?

The phrase "what organizational variables" does not imply that there is one set, or a best set of organizational variables. Given limited time, resources, and data, every possible organizational variable could not have been investigated for its relationship with the criterion. Rather, a certain set of organizational variables was proposed for study

[1] The criterion problem is dealt with in detail in section 2.3.

that were identified as promising by other empirical research efforts, or fit the writer's conceptual framework. Once this promising set had been identified, the relationships of the candidate variables to the criteria were tested.

A note on the term "organizational" variables is in order. The use of the term is meant to convey the concept of variables over which the organization has some control - not necessairly strict organizational properties like organizational structure, etc. It includes some strict organizational properties - (e.g. size), but also some group properties over which the organization has control (e.g. average length of group membership), and some supervisor variables over which the organization has control (e.g. extent of participation).

Extra organizational variables were excluded from the scope of the study.

The output of scientists and engineers appears to be multidimensional. Taylor, Smith and Ghiselin (1961) factor analyzed 52 variables of researcher's contributions and found 15 dimensions. Two dimensions of scientific/engineering output of particular importance were innovativeness and productivity. Innovation was of importance because in theory it is the essence of R&D Laboratories - i.e. original and useful knowledge, theory, products, processes, publications, etc. Productivity was of interest due to its potential relationship with innovation. The dimensions are dealt with in detail in the criterion section (2.3).

The output of scientists and engineers was the criterion in this study. Personal abilities, like creative ability or creativity, were not the subject of this dissertation.

Only scientists, engineers and their immediate supervisors were subjects in this study. Technicians, secretaries and other support personnel were excluded.

Since the writer was an Air Force Officer and entry into several Air Force R&D Laboratories was easily obtained, the sample consisted entirely of scientists and engineers in Air Force R&D Laboratories.

1.3 Research Objectives

1. Identify organizational variables that appeared to be promising as correlates of innovation and productivity of scientists and engineers.

2. Develop an instrument to measure the extent to which the variables exist.

3. Develop definitions of innovation and productivity.

4. Design a technique to measure the innovativeness and productivity of scientists and engineers.

5. Using the measures of organizational variables, innovation and productivity, collect data on a sample of scientists and engineers in Air Force R&D Laboratories.

6. Test the relationships of the organizational variables with innovation and productivity.

Before proceeding with the design of the experiment, relevant literature is reviewed.

PART 2

LITERATURE REVIEW

Anyone familar with the literature dealing with productivity or innovation knows that organizational climate has become a major theme in that literature. Therefore, a review of the literature dealing with organizational climate was needed.

2.1 Organizational Climate

Recently, the term organizational climate has come into increasing use in the literature. Its use is proportional to the variability of conceptual and operational definitions of the term.

This section attempts to demonstrate, through examination at the conceptual and operational levels, that certain unresolved issues surround the construct. Thus, more work needs to be done at the conceptual level and therefore, organizational climate is not necessarily as relevant to the current research as it would appear.

2.1.1 Conceptual Definitions

In their recent thorough literature review of the subject, Hellriegel and Slocum (1974) seemed to implicitly accept the organizational climate concept as they addressed themselves to the operational level treatment of organizational climate. They remarked: "The primary criticism of the construct seems to exist at the operational rather than the con-

ceptual level." (p.257)

Benjamin Schneider, one of the most prolific writers on the subject of organizational climate, assumed an opposing position. Schneider (1974) wrote: "However, it will be argued here that since operationalization presupposes conceptualization it is precisely at the conceptual level where the problems lie." (p.1)

James[1] and Jones (1974) in their thorough critical review of organizational climate sided with Schneider, and even stated that the conceptual problems cannot be solved now. They wrote:

> "Only after the conceptual boundaries of organizational climate are spelled out should the measurement and operationalization become matters of major concern. With respect to organizational climate, the present authors feel that a definitive conceptual statement of the nature of organizational climate is not possible at the current stage of research." (p.1107)

This dissertation attempted to demonstrate that issues exist at both levels. However, it is obvious that trying to resolve the operational level problems without first solving the conceptual problems is like treating the symptoms of a disease while ignoring the cause.

The range of definitions of organizational climate is large. Table I is offered as a sampling of definitions.

[1] James's conversion to the ranks of organizational climate critics is noteworthy because he is coauthor of an organizational climate study that praised the predictive powers of organizational climate (Ellison, McDonald, James, Fox and Taylor, 1968).

TABLE I - ORGANIZATIONAL CLIMATE DEFINITIONS

AUTHORS	ORGANIZATIONAL CLIMATE DEFINED AS [2]...	COMMENTS
Evan (1968)	... "a multidimensional perception of the essential attributes or character of an organizational system." (p.110)	1. The dimensions or essential attributes were not specified. 2. Perceptions of members and nonmembers were included. 3. No necessary effect on behavior was required.
Forehand and Gilmer (1964)	... "the set of characteristics that describe an organization and that (a) distinguish the organization from other organizations, (b) are relatively enduring over time, and (c) influence the behavior of people in theory." (p.362)	1. Both objective and perceptual measures were recognized. 2. The characteristics were assumed to influence behavior. (This feature appeared in several other definitions).
Frederiksen (1969)	... "an expectation held by most of the membership of an organization as to a kind of uniformity in behavior that is seen as appropriate for the group." (p.641)	1. How does this differ from group norms?

2 Emphasis added throughout.

TABLE I - continued

AUTHORS	ORGANIZATIONAL CLIMATE DEFINED AS ...	COMMENTS
Friedlander and Greenberg (1971)	... "an interaction of personal factors (personality, needs, values, etc.) and organizational properties (structure, supervisory practices, etc.). (p.289)	1. In spite of examples of factors/properties listed, authors measured only supportiveness.
Greiner, Leitch and Barnes (1968)	... "the ways in which an organization is seen as fitting together task and people inputs in handling its key problem areas." (p.204)	1. Ways were tied to the Managerial Grid of Blake and Mouton (1964).
Hall and Lawler (1969)	... "the individual's subjective impressions of, or associations with, his organization." (p.350)	
Halpin and Croft (1962)	... "the organizational "personality" of a school." (p.1)	1. Authors subsequently measured only social component of the organizational climate.
Hellriegel and Slocum (1974)	... "a set of attributes which can be perceived about a particular organization and/or its subsystems, and that may be induced from the way that organization and/or its subsystems deal with their members and environment." (p.256)	

TABLE I - continued

AUTHORS	ORGANIZATIONAL CLIMATE DEFINED AS ...	COMMENTS
Kallick (1964)	... "an aura which emanates from top individuals downward reflecting their policies, ideals and goals, which may or may not be formally stated but which affect the behavior of others." (p.45)	1. Only top individuals were the source of organizational climate.
Litwin and Stringer (1968)	... "the perceived, subjective effects of the formal system, the informal "style" of managers, and other important environmental factors on the attitudes, beliefs, values, and motivation of people who work in a particular organization." (p.5)	1. Are the effects on attitudes, beliefs, values, and motivations, properties of people or organizations?
Pritchard and Karasick (1973)	... "a relatively enduring quality of an organization's internal environment distinguishing it from other organizations; (a) which results from the behavior and policies of members of the organization, especially top management; (b) which is perceived by members of the organization; (c) which serves as a basis for interpreting the situation; and (d) acts as a source of pressure for directing activity." (p. 126)	1. Top management was primary determinant of organizational climate. 2. Do parts (b) and (d) imply group norms?
Schneider (1974)	... "the concepts people share about the organization. As concepts, climate perceptions are meaningful abstractions of sets of cues, the cues being the many specific events, conditions, practices, and procedures that occur in the daily life of an organization. As concepts, climate perceptions help individuals	1. Schneider stressed the importance of shared perceptions.

TABLE I - continued

AUTHORS	ORGANIZATIONAL CLIMATE DEFINED AS ...	COMMENTS
Schneider (1974) cont'd	reduce information overload and function as frameworks against which people identify behaviors that will adopt them to their situation." (p.20)	
Tagiuri (1968 b)	... "a relatively enduring quality of the internal environment of an organization that (a) is experienced by its members, (b) influences their behavior, and (c) can be described in terms of values of a particular set of characteristics (or attributes) of the organization." (p.27)	1. Tagiuri (1968 b) posed the problem of "What elements or aspects of the environment should be focused on ?" (p.14)
Taylor and Bowers (1970)	... "a term (a) referring to a psychological trait rooted in the realm of perception with regard to certain organizational stimuli; (b) becoming a sociological property of a group through interpersonal communication; (c) operating as a conditioning effect upon overt behavior within the organizational context." (p.98)	1. Are the psychological traits and sociological properties characteristics of individuals, groups, or organizations? 2. How does this differ from group norms?

The range of conceptual definitions causes one to wonder if the cited authors were all defining the same construct. From the table, organizational climate was variously seen as: a multidimensional perception; the set of characteristics; an expectation; an interaction; the ways of integrating; the subjective impressions; the organizational personality; a set of attributes; an aura; the perceived, subjective effects; a quality; shared concepts; or a phychological trait becoming a sociological property. Perhaps such divergence implies that the construct has not been well thought out. After reviewing the above definitions, one could still ask: "What is organizational climate?"

Analysis of the various organizational climate conceptualizations uncovered several unresolved issues.

2.1.1.1 Dimensionality. Many of the preceding definitions implied a global concept of organizational climate. Yet, the attempts to measure organizational climate usually investigated only parts or specific dimensions of organizational climate. This global conceptualization and subsequent specific measurement (with little attempt[3] to formulate a global measurement) raised a question. Is the climate construct truly global?

If it is global, what utility is there (other than gross typology) in describing a climate as open or closed per Halpin and Croft (1962), or System I through System IV per Likert (1967)?

[3] Exceptions are Halpin and Croft (1962) and Likert (1967).

If organizational climate is so all emcompassing that it can be measured only in parts or separate dimensions, another issue arises. Forehand and Gilmer (1964) posed the question of how does one combine the parts into the whole. Is the combination of dimensions an equal weighting, a linear combination, a non-linear combination, or a series of interactions?

If it can be measured only via its separate dimensions, what is the totality of dimensions that describe the whole concept? Several cited authors gave some examples but a total list is not apparent. (This question is dealt with further in a subsequent section).

2.1.1.2 Effect on behavior and redundancy with group norms. Many of the preceding authors assumed that organizational climate influences the behavior of the people in the organization.[4] Yet, few authors checked this assumption by collecting data with behavior as the criterion and organizational climate as the predictor.

An interesting argument in circular reasoning can be advanced. If a conceptual definition stated that organizational climate influences behavior, and if subsequent studies operationalizing the concept treated behavior as the dependent variable, and if the studies showed no significant effect on behavior due to organizational climate (ceteris paribus) does that mean, by definition, that the phenomenum

[4] Evan (1968) is a notable exception.

investigated was not organizational climate?

If the ideas of effect on behavior and perceptions shared by the group are accepted, how does organizational climate differ from group norms at the conceptual level? The definitions of organizational climate in Table I offered by Frederiksen (1969), Pritchard and Karasick (1973), and Taylor and Bowers (1970) that stressed these two features are not unlike the idea of group norms as expressed by Golembiewski (1965). What utility does the organizational climate construct possess if it is redundant with group norms?

Another area of redundancy is with job satisfaction.

2.1.1.3 Redundancy with job satisfaction. A controversy exists in the literature concerning the relationship of organizational climate to Job Satisfaction.

On the one side, Schneider (1974) remarked: "climate perceptions behave differently from satisfaction." (p.15)

In opposition, Guion (1973) took the position that a perceptual measure of organizational climate [5] was the same old construct of job satisfaction under a new name. Supporting Guion's stance, Johannesson (1973) presented the results of a study in which he cluster analyzed the scores from a perceptual organizational climate questionnaire and a job satisfaction questionnaire. After observing dimensions that have high loadings of both satisfaction and climate, he con-

[5] Perceptual measures are by far the most often used.

cluded that perceptually measured organizational climate and job satisfaction are redundant.

Similarly, Downey, Hellriegel, Phelps and Slocum (1974) reported the results of a study in which they factor analyzed a job satisfaction instrument and an organizational climate instrument, and examined the correlations of the resulting dimensions. Even after controlling for organizational level and job performance, almost one half of the total possible number of correlations between the job satisfaction dimensions and organizational climate dimensions were significant. The authors concluded that further research was needed on the question of the redundancy of the two constructs.

Some correlational studies lend further support to the redundancy position. Lawler, Hall and Oldham (1974) presented a study in which the median correlation of organizational climate with job satisfaction was .47, whereas the median correlation of organizational climate with organization performance was .25. Pritchard and Karasick (1973) reported a median correlation of .48 between organizational climate and satisfaction, and a median correlation of .05 between organizational climate and performance. Friedlander and Margulies (1969) reported correlations ranging from .54 to .73 between organizational climate and measures of satisfaction.

The preceding studies do not prove that job satisfaction and organizational climate are totally redundant. They do suggest that the job satisfaction and organizational

climate constructs are not independent.

2.1.1.4 People or organizations. The relationship of perception and attidude concerning the organization is another unresolved issue surrounding the organizational climate construct. Hellriegel and Slocum (1974) remarked that the intent of organizational climate measures is to record how the individual perceives facts, not whether he "likes" them or not. However, they subsequently remarked: "Factors such as attitudes, values, and motives are widely recognized as playing an important role in the perceptual process" (p.257). Citing evidence from one of his studies, Guion (1973) wrote: "... perception can be used to infer attitude" (p.123).

The perceptual organizational climate school argues that perceptions are descriptions of fact and thus perceptual organizational climate measures are recording characteristics of organizations. However, since perceptions and attitudes are confounded, perhaps perceptual organizational climate measures are recording attitudes, which are characteristics of people. This may be responsible for Taylor and Bowers (1970) having used the term "psychological trait" (p.98) when identifying organizational climate, and for Insel and Moos (1974) having used the term "psychological environments" (p.179) for organizational climate. Perhaps the perceptions of an individual concerning his organization or environment, which are confounded with his attitudes, are more a reflection of

his individual psychological climate than the organization. If this is so, use of the term organizational climate in reference to individual perceptions is misleading. Guion (1973) summed up the issue by remarking: "There seems to be real confusion over whether "climate" refers to attributes of organizations or attributes of people." (p.121)

In fact, the only major source of variance concerning the organization at the individual level is the individual - not the organization. Within an organizational unit, organizational structure, policies, supervisor, peers, etc. have near zero variance. Thus, recording variances in individual perceptions and labeling those variances as attributes of organizations is misleading. Between organizational units, some facets of the organization are different, e.g. supervisors, peers, etc. But even in this case, one measuring individual perceptions would have no way of knowing if the variance is due to real differences in the organizational variables or differences in attitudes, etc., of the individuals. One possible answer for both the within and between case is to use a central tendency measure (e.g. mean or mode) of the perceptions of the individuals within the organizational unit. This eliminates variance due to individuals. More is said about this technique in a later section.

Unfortunately, this writer was unable to resolve the preceding issues. It is concluded that they are significant enough to preclude use of the organizational climate construct.

2.1.2 Operational Definitions

Table II contains summaries of all the original organizational climate studies reviewed. The term original studies means studies with either the first derivation of dimensions from an instrument, or subsequent derivations of modified dimensions. Methodology refers to method of deriving the dimensions.

Attention is focused on the dimensions in the hope that such analysis will reveal commonalities to aid in the definitional process, and will answer some of the questions raised in a preceding section on dimensionality. Caution is in order when examining the studies that employ the technique of factor analysis. It is recognized that titling factors derived from this technique is judgemental, and that different guidelines exist for determining the number of factors (dimensions). Thus, comparison with studies wherein the dimensions are defined a priori is approximate.

Analysis of Table II reveals no dimensions that appeared in a majority of the studies. Dimensions like autonomy, structure, reward, support and warmth, leadership, and standards appear in five to seven of the studies. But five to seven agreements out of 22 formulations hardly is indicative of widespread concensus concerning the dimensionality of organizational climate, especially when some of the formulations were solely due to literature reviews. Thus, the various operational definitions of the construct did not resolve the dimensionality issue.

TABLE II - ORIGINAL ORGANIZATIONAL CLIMATE STUDIES

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Burns and Stalker (1961)	Mechanistic vs. Organic	Interview	Chief Executive Officer and managers in 20 firms	Management System	Independent Variable: Extrinsic Factors. Management System should be a function of rates of technological or market change.
Campbell, Dunnette, Lawler and Weick (1970)	(1) Autonomy (2) Structure (3) General Reward (4) Warmth and Support	Literature Review			
Davis (1968)	Rule Following	Dimension Selected in Advance	54 Executives in 5 government organizations	Organizational Climate	Independent Variable: Organizations. Organizations had their own rule following propensities.
Dewhirst (1971)	Desire to Manage	Dimension Selected in Advance	320 managers and nonmanagers in 2 development organizations	Organizational Climate	Independent Variable: Organizations. Organizations fostered different desires to manage.

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Forehand and Gilmer (1964)	(1) Size (2) Organization Structure (3) Systems Complexity (4) Leadership Pattern (5) Goal Direction	Literature Review			
Frederiksen (1969)	(1) Global vs. Detailed Supervision (2) Innovation vs. Rules	Predetermined Experimental Dimensions	260 state of Ca. executives	Productivity	Independent Variable: Organizational Climate. Productivity was reduced by incompatible climates.
Friedlander and Greenberg (1971)	(1) Support from Peer Workers (2) New Worker Treatment (3) Support from his Supervisor	Preliminary Interviews	478 hard core unemployed	Performance	Independent Variable: Organizational Climate. Hard core unemployed who perceived their climate as supportive also tended to be rated by their supervisor more favorably in terms of work effectiveness and work behavior.

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Greiner, Leitch and Barnes (1968)	Managerial Grid Dimensions (1) Task (2) Human	Dimensions Selected in Advance	3,042 managers, accountants and lawyers in 8 IRS district Offices	Organizational Climate	Independent Variable: Districts and Managerial Grid Training. Organizational Climate was uniform across the 8 districts and Managerial Grid Training failed to produce changes in Organizational Climate.
Hall and Lawler (1969)	(1) Competence (2) Morality (3) Emotional Control (4) Risk-Taking (5) Dominance	Factor Analysis	Research Directors of 117 R&D Labs	Organizational Climate	Independent Variable: Performance. Hi performers showed higher scores on dominance and lower scores on emotional control than did the lo performers. The hi performing R&D lab was seen by its director as being dominant, hard, superior, active and competitive.
Halpin and Croft (1962)	Characteristics of the Group (1) Disengagement (2) Hindrance	Factor Analysis	1,151 teachers and Principals in		

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Halpin and Croft (1962) cont'd	(3) Esprit (4) Intimacy Behavior of the Leader (5) Aloofness (6) Production Emphasis (7) Thrust (8) Consideration		71 Elementary schools		
Kaczka and Kirk (1968)	(1) Grievance Behavior (2) Cost Emphasis (3) Leadership Style (4) Congruence of Leadership Style (5) Attitudes of Industrial Engineering Dept.	Dimensions selected in advance	Data from Institute for Social Research into Computer Simulation Model	Organizational Performance, Group Pressure	Independent Variable: Managerial Climate. Employee - oriented climate correlated negatively with group pressure and correlated positively with Organizational Performance.
Likert (1967)	(1) Leadership (2) Motivational forces (3) Communication (4) Interaction-Influence (5) Decision-Making				

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Likert (1967) cont'd	(6) Goal-Setting (7) Control (8) Performance Goals and Training	Dimensions selected in advance			
Litwin and Stringer (1968)	FORM "A" (1) Structure (2) Responsibility (3) Reward (4) Risk (5) Warmth and Support (6) Expect Approval (7) Conflict	Logical Grouping of responses to open-ended questionnaire	45 paid subjects in Laboratory Experiment	Motivation Satisfaction Performance	Independent Variable: Leadership Style. Leadership style was important determinant of climate which was an intervening variable.
	FORM "B" (1) Structure (2) Responsibility (3) Reward (4) Risk (5) Warmth (6) Support (7) Standards (8) Conflict (9) Identity	Revision of Form A	19 girls in service dept. of public utility	Satisfaction Absenteeism Turnover Performance	Independent Variable: Organizational Climate. Dissatisfaction, serious absenteeism and turnover, and below average performance coincided with poor match between motives of girls and motives aroused by climate.

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Litwin and Stringer (1968) cont'd			Employees in 2 chemical plants. N not reported.	Organizational Climate	Independent Variable: Change in Management. Higher Warmth, Identity, Reward, Responsibility, Risk, Standards reported for 1 plant after a change in Management.
			7 Depts. in Plastics group in new product development 30-50 people per dept.	Organizational Climate	Independent Variable: Department. Each Department had a distinct Organizational Climate. Different Organizational Climates partly determined by different tasks.
Meyer (1968)	(1) Constraining Conformity (2) Responsibility (3) Standards (4) Rewards (5) Organizational Clarity	Factor Analysis of Litwin and Stringer's (1968)	350 Professional and Clinical employees in 2	Organizational Climate	Independent Variable: 2 plants and 2 groups within 1 plant. Differences in climate between the 2 plants and

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Meyer (1968) cont'd	(6) Friendly, Team Spirit	questionnaire	General Electric plants		between the 2 groups were noted.
Pace (1968)	(1) Intellectual or scholarly dimension (2) Humanistic and esthetic matters (3) Vccational/ pragmatism (4) Friendliness, affiliation, social orientation (5) Social Conformity	Literature Review of various college climate studies			
Payne and Pheysey (1971)	(1) Organizational Progressiveness (2) Normative Control (3) (No obvious title) (4) (No obvious title) (5) (No obvious title)	Factor Analysis	120 junior managers from more than 100 different firms		

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Pritchard and Karasick (1973)	(1) Autonomy (2) Conflict vs. Cooperation (3) Social Relations (4) Structure (5) Level of Rewards (6) Performance Reward Dependency (7) Motivation to Achieve (8) Status Polarization (9) Flexibility and Innovation (10) Decision Centralization (11) Supportiveness	Dimensions selected in advance	76 managers	Satisfaction Performance	Independent Variable: Organizational Climate. Organizational Climate was more highly related to Job Satisfaction than to individual performance.
Schneider and Bartlett (1968)	(1) Managerial Support (2) Managerial Structure (3) New Employee Concern (4) Intra- Agency Conflict (5) Agent Independence	Factor Analysis	143 Managers in 2 insurance firms		

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Schneider and Bartlett (1968) cont'd	(6) General Satis - faction				
Schneider and Hall (1972)	(1) Superior Effectiveness (2) Supportive Autonomy (3) Work Challenge (4) Personal Acceptance	Factor Analysis	373 Catholic Priests	Organizational Climate	Independent Variable: Activities Performed. Activities performed (parochial, administrative, community involvement, and personal development) were related to Organizational Climate.
Tagiuri (1968)	(1) Direction and Guidance (2) Professional Atmosphere (and status base) (3) Qualities of Superiors (4) Qualities of Dept. (or group) (5)Results, Autonomy and Satisfaction	Factor Analysis	232 executives in Management Programs at Harvard		

TABLE II - continued

AUTHORS	CLIMATE DIMENSIONS	METHODOLOGY	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Taylor and Bowers (1970)	(1) Technological Readiness (2) Human Resources Primacy (3) Communication Flow (4) Motivational Conditions (5) Decision Making Practices	Smallest Space Analysis	4,500 Individuals (all hierarchical levels) in 3 industrial organizations		

Table III contains summaries of the follow-on organizational climate studies reviewed by this writer. Follow-on means studies that employed previously derived instruments or dimensions. Those studies were examined in addition to the studies in Table II to gather further evidence for the issues of effect on behavior and redundancy with job satisfaction.

Table III references the Friedlander and Margulies (1969) study cited earlier on organizational climate and satisfaction. The table also contains a number of studies that tested organizational climate as the dependent variable, not as the predictor of behavior alluded to in several definitions.

2.1.3 Conclusion

Examination of conceptual definitions of organizational climate causes one to note the divergence of definitions. Unresolved issues surrounding the conceptualization concern the dimensionality of the construct, its effect on behavior and redundancy with group norms, its redundancy with job satisfaction, and its people or organizational orientation.

Analysis of the operational treatments of organizational climate underscored the variability of the dimension. Some studies supported the confounding of organizational climate with job satisfaction.

TABLE III - FOLLOW-ON ORGANIZATIONAL CLIMATE STUDIES

AUTHORS	CLIMATE INSTRUMENT	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Dieterly and Schneider (1974)	Constructed along 4 dimensions of Campbell, et al. (1970)	120 students in laboratory study	Organizational Climate	Independent Variable: Position Level, degree of participation in decision making, and organizational philosophy toward customers. Climate perceptions seemed to be attributable to customer or stockholder orientation and 2 interactions: Organizational orientation with level of participation and level of participation with position level.
Friedlander and Margulies (1969)	Slightly modified Halpin and Croft (1962)	95 production workers	Job Satisfaction	Independent Variable: Organizational Climate. (1) Organizational Climate was a significant determinant of individual satisfaction. (2) The degree of impact of climate upon satisfaction varied with the type of climate and type of satisfaction. (3) The work values held by individuals moderated these relationships.
Golembiewski and Carrigan (1970)	Likert (1967)	10 regional sales managers in 1 firm	Organizational Climate	Independent Variable: Sensitivity Training. Sensitivity Training produced changes in organizational cli-

TABLE III - continued

AUTHORS	CLIMATE INSTRUMENT	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Golembiewski and Carrigan (1970) cont'd				mate over 18 month period. Other occurrences (managerial job reclassification, profound change in % of time in managerial work) confounded results.
Golembiewski, et al. (1971)	Likert (1967)	43 sales managers from 2 hierarchical levels in 1 firm	Organizational Climate	Independent Variable: Sensitivity Training and External Environment. Sensitivity Training coupled with poor external environment (dull to declining market, threat of reduction in force) resulted in non-significant changes in organizational climate.
Marrow, Bowers and Seashore (1967)	Likert (1967)	27 managers and supervisors in a manufacturing plant	Profitability Productivity Turnover Absenteeism	Independent Variable: Changes in: top management; organization; reward system; training; maintenance; management system. Intervening Variable: Organizational Climate. The climate shifted toward System IV, profitability up 32%, productivity up 26%, turnover down 60%, absenteeism down 50%.

TABLE III - continued

AUTHORS	CLIMATE INSTRUMENT	SUBJECTS	DEPENDENT VARIABLE	FINDINGS
Roussell (1974)	Halpin and Croft (1962)	205 teachers in 10 senior high schools	Organizational Climate	Independent Variable: Sex of Dept. Head. A significant relationship between the sex of the dept. head and 3 of the 8 climate dimensions (esprit, intimacy and hindrance)was noted.
Schneider (1972)	Schneider and Bartlett (1968)	1,125 life insurance agents, assistant managers and managers	Organizational Climate	Independent Variable: Hierarchical level. On 3 of 6 dimensions (support, conflict and concern), managers seemed to view the agency more positively than assistants, and assistants viewed the agency more positively than agents.
Sorcher and Danzig (1969)	Meyer (1968)	Engineering, marketing and financial groups in General Electric, Syracuse	Organizational Climate	Independent Variable: Feedback. Managers using feedback had changes in organizational climate.

Due to the foregoing shortcomings, it is suggested that more work needs to be performed at the conceptual level. Specifically, more attention is required to define what is included in the term (i.e. the dimensionality issue), and to clarify the people vs. organization issue, and its relationship with job satisfaction. If these questions can be dealt with successfully, then the question of effect on behavior might be explored with more clarity. Until then, its comprehensibility is elusive and its utility is debatable.

However, it is doubted that all the questions can be resolved. The people vs. organization issue seems to be an intrinsic handicap.

In addition to outright rejection of the use of organizational climate in this study, at least two other separate messages became clear. First, no attempt was made to present a unifying construct that tied together all the organizational variables. Second, measurement of an organizational variable via the perception of an individual was not attempted. When such a measure was obtained, it was not treated as a measurement of the organization, but rather a measure of the individual.

Once the organizational climate concept had been rejected, a search for organizational variables from relevant empirical studies was begun.

2.2 Organizational Variables

2.2.1 Review of Empirical Studies

Hoping to identify a preliminary set of organizational variables for possible inclusion in this study, the literature was combed for empirical studies. The studies related specific organizational variables with a measure of output of scientists and engineers in an R&D setting, or with a measure of original output in a controlled laboratory experimental setting. One might question the applicability of some of the controlled laboratory experiments to a R&D setting. However, since the purpose was to identify a preliminary set of variables for futher testing, the point is not argued. Table IV is a summary of the studies.

Several lessons are apparent from Table IV.

First, the variety of measures employed, both of organizational variables and of criteria measures, severely hampers comparison and contrast of the studies. Comparison is also hampered by the different levels of analyses, ranging from the individual to the entire laboratory.

Second, several studies used the organizational climate approach of relating individual perceptions of organizational variables to individual output measures.

Third, the variance of criterion measures employed, all with the same label of creativity or innovation, is astounding.

TABLE IV - ORGANIZATIONAL VARIABLES AND OUTPUT

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Anderson and Fiedler (1964)	Participatory vs. Supervisory Leadership.	Experimentally arranged conditions via instructions to leaders.	1. Judge ratings of originality of plot, plot elaboration, expressiveness of language, suspense and humor of stories written for TAT pictures. (Total score was qualitative TAT score whereas total number of words was quantitative TAT score). 2. Judge ratings of originality of unusual uses proposed for 2 common objects. 3. Judge ratings of quality of arguments produced for hypothetical issue and quantity of arguments. 4. Judge ratings of quality of solutions proposed to a hypothetical problem and quantity of solutions.	30 four man groups of male undergraduate Naval ROTC students.	1. Laboratory experiment. 2. Stress was induced by the presence of Navy officers, and subjects were told that their performance would be evaluated and made part of their record. 3. Significant differences due to leadership were noted for originality of unusual uses, quantity of arguments, and quality of solutions. The other four criteria were not significantly differentiated due to leadership.

TABLE IV- continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Andrews and Farris (1967)	Supervisory Behavior: 1. Task Functions a. Technical Skills b. Critical Evaluation c. Influence on goals 2. Human Relations Functions: a. Motivating Others b. Let Know Where Stand c. Sensitivity 3. Administrative Functions a. Plan and Schedule b. Inter-Group Relations 4. Leadership Styles a. Use of Consultation b. Freedom.	Group Rating (average of members) of statements on questionnaire concerning supervisory behavior.	Average for group of peer and supervisor rating of innovation of individuals. The measure was adjusted for the individual's experience, seniority and formal training.	94 non-supervisory scientists in 21 small groups at a NASA research center.	1. Statistical significance not reported. 2. Differences in innovation between the teams were noted. 3. The relation - ship between supervisory task functions and group innovation was positive. Human relations functions and administrative functions were both negatively related to group innovation. Leadership styles did not exhibit a strong relationship with the criterion.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Andrews and Farris (1972)	Time Pressure.	Questionnaire completed by subjects reporting amount of time pressure experienced.	Supervisor and peer ranking (for the preceding 5 years): 1. Innovation 2. Productiveness 3. Usefulness The measures were adjusted for experience, seniority and formal training.	118 scientists and engineers in a NASA research division.	1. Time lagged correlation indicated that time pressure was significantly related to innovation and usefulness, but not to productiveness. 2. Comparison of (experienced - optional) pressure with innovation and productiveness was curvilinear, and with usefulness was linearly positive.
Andrews and Gordon (1970) Study I	1. Responsibility for initiating new activities 2. Influence in decision-making 3. Sense of professional security	Individual's perception of his laboratory environment.	1. Judge ratings of innovativeness of individual's research output. 2. Remote Associates Test measured creative ability.	115 project directors in research laboratories.	1. Significance of items 1-6 not reported. Positive relationship noted. 2. Simultaneous presence of items 1-4 produced significant positive correlation between innovativeness and creative

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Andrews and Gordon (1970) Study I cont'd	4. Superior non-interference 5. Small project 6. Diversity.				ability. 3. Presence of less than first 4 items produced negative correlations between innovativeness and creative ability.
Andrews and Gordon (1970) Study III	Cognitive Sensitivity of Group.	Gordon's Social Differentiation Scale.	1. Judge ratings of originality and quality for creative solution to problems. 2. Remote Associates Test meaured creative ability.	3-man groups of undergraduates	1. Lab experiment. 2. Significance not reported. But authors noted negative relationship between creative ability and criterion for hi sensitivity and vice versa. 3. Authors noted much evaluation in hi sensitivity group and concluded that freedom from early evaluation enhanced innovation.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Aram, Morgan and Esbeck (1971)	Interpersonal Collaboration: 1. Support and Integration 2. Open, Authentic Communication 3. Knowledge-Based Risk Taking.	1. Questionnaire completed by individual subjects. 2. Group measure was the average of the perceptions of individual group members.	1. Organization's individual performance rating system. 2. Technical council ranking of overall-performance of groups.	1. 110 scientists and engineers in the R&D center of an industrial organization. 2. 16 product line groups.	1. Knowledge-based risk taking was significantly related to individual performance. 2. No items were significantly related to group performance.
Connor (1974)	Interpersonal Competence.	Social Adroitness Scale.	1. Peer rating of scientific research competence. 2. Remote Associates Test measured creative ability.	28 scientists in a research oriented unit of a university and 36 scientists in an independent research lab.	1. Creative ability had a low relationship with research competence. 2. Statistical significance not reported. 3. Interpersonal competence was a moderator variable between creative ability and scientific research competence.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Connor (1974) cont'd					4. Relationship between interpersonal competence and research competence was moderate.
Ellison, McDonald, James, Fox and Taylor (1968)	1. General Organizational Climate 2. Biographical items 3. Work Group, Branch, Division, Dept. and Laboratory in general. 4. Actual + Ideal laboratory situation 5. Actual + (constant-ideal) laboratory situation 6. Associates and Supervisory personnel 7. 1-6 above were subscores each consisting of many items.	Questionnaire completed by individual subjects that attempted to measure various aspects of Organizational Climate.	1. Supervisory Rankings: a. Communication b. Skill with People c. Creativity (Originality and Applicability) d. Productivity 2. Quality of Publications 3. Quantity of Publications 4. Awards received 5. Promotion Rate 6. Peer nominations: a. person most productive b. person best suited to "give new problem to" 7. Both unadjusted and adjusted	165 scientists in 1 government research laboratory.	1. Creativity ranking associated with quality of publications but not with quantity of publications. 2. Productivity rankings associated with quantity of publications. 3. Subscores 1 and 3 had most significant cross validities on several criteria. Other subscores had few significant contributions.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Ellison, McDonald, James, Fox and Taylor (1968) cont'd			criteria used. 8. Criterion 1 adjusted for: a. Time on Major Project b. education c. Type of work (basic, applied operational) 9. Criterion 5 adjusted for experience and education.		
Evan (1965)	1. Interpersonal Conflict: Peers 2. Interpersonal Conflict: Supervisor-Subordinate 3. Technical Conflict: Peers 4. Technical Conflict: Supervisor-Subordinate.	Questionnaire administered to individual project group members.	Average rating: 1. Self-rating of project group productivity 2. First level Supervisor rating of project group productivity. 3. Second level Supervisor rating of project group productivity.	In a government research laboratory: a. 82 scientists and engineers associated with 27 projects; b. 27 first level	1. Organizational variable (1) was statistically significant for the government project groups but not for the industrial project groups. 2. Organizational variables 2,3 and 4 were not significant in either laboratory.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Evan (1965) cont'd				supervisors; c. 27 second level supervisors. 2. In an industrial development laboratory: a. 159 scientists and engineers associated with 37 projects; b. 30 first level supervisors; c. 30 second level supervisors.	

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Farris (1969)	1. Involvement 2. Influence 3. Contact 4. Diversity 5. Salary 6. Number of subordinates.	Questionnaire completed by individual subjects.	1. Self report: a. Number of patents or patent applications b. Number of unpublished reports 2. Supervisor and peer rankings (converted to percentiles): a. Contribution to general technical or scientific knowledge in the field. b. Overall usefulness in helping the organization carry out its responsibilities. 3. The measures were adjusted for: a. Highest degree earned b. Time since receiving highest degree c. Time within laboratory.	125 engineers in 3 laboratories of an electronics corporation.	1. Study used some data from Pelz and Andrews (1966). 2. All 6 factors were significantly related to some of the criteria. 3. Through use of measurements at different times and time lagged correlational analysis, relationships were stronger when performance was measured before the organizational factor.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Fiedler and Barron (1967)	Leadership Style	Fiedler's Least Preferred Co-worker (LPC) scale.	Judge ratings of originality of title, creativity of plot, elaboration, story structure, sentence structure, expressiveness, humor and suspense of fables written by teams.	54 3-man teams of male undergraduate Army and Navy ROTC students.	1. Lab Experiment. 2. The relationship between leadership style and the criterion was not significant. 3. Stress was induced by the presence of military officers.
Gibb (1951)	1. Group Size 2. Threat Reduction.	1. Group varied in size containing 1,2,3,6,12, 24,48 or 96 members. 2. Threat was reduced by the experimenter reading a different set of instructions.	Number of solutions and judged "goodness" of solutions to a series of problems.	1,152 college students.	1. Lab Experiment. 2. Size was correlated positively with number of solutions and threat reduction had a significant positive correlation for number and quality of solutions.
Gordon and Marquis (1966)	1. Freedom 2. Visibility of Consequences.	Questionnaire administered to subjects evaluating 1 and 2 relative to administrative superior.	Judge ratings of innovation of project summary reports.	245 project directors of research in the	1. Visibility of consequences interacted with freedom to yield a significant effect on innovation.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Gordon and Marquis (1966) cont'd				social-psychological aspects of disease: a. 64 in universities b. 57 in health agencies c. 38 in medical schools d. 20 in hospitals and clinics.	2. The statistical significance of freedom or visibility by themselves was not discussed.
Hall and Lawler (1970)	1. Job Characteristics: a. Wide Range of Projects b. Independent Budget c. Job Challenge d. Direct Customer Responsibility.	Questionnaires and Interviews: 1. Director's perceptions of 1b and 1d. 2. Mode of professional's perceptions in an organization used for other items.	1. Global Technical and Administrative Performance-Self rating by directors. 2. Objective Performance (Sum of): a. Change in budget b. Number of new contracts	22 directors of research and 291 professionals in 22 R&D organizations in Conn.	1. Direct Customer Responsibility and Financial Goals Pressure were significantly correlated with the global measure. 2. Quality pressure was significantly correlated

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Hall and Lawler (1970) cont'd	2. Pressures: a. Time b. Financial Goals c. Quality.		c. Number new projects d. % projects on schedule e. Number contracts renewed f. % projects on *cost budget* 3. Composite Performance (Sum of 1 and 2).		with all 3 criteria. 3. The other items were not significant.
Harrison (1974)	1."Bottom-up" Communication 2."Top-down" Communication 3. Identification with Management objectives 4. Definition of duties and responsibilities 5. Participation in Determination of projects 6. Participation in establishment of man-	Questionnaire completed by individual subjects that rates items on a scale of 1-4.	Perceived role performance: 1. Esteem of fellow scientists 2. Contribution to Knowledge in Field 3. Contribution to Management Objectives 4. Sense of Personal Achievement.	95 scientists in 3 large laboratories. The work ranged from basic research to product development (all in physics).	1. Study was designed to test relationship of perceived role performance to organic system of management. 2. Organizational variables 6,7,9, 10,11 and 14 were significantly correlated to criterion 2 for the scientists in one of the laboratories and 5 and 12 were significant in 2 of the laboratories.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Harrison (1974) cont'd	agement objectives 7. Freedom to publish 8. % of time spent on work approved in advance by management 9. Time spent thinking about resigning or taking leave of absence 10. Relationship (rapport) with organizational supervisor 11. Compatibility of personal goals and management objectives 12. Sense of commitment to management objectives 13. Freedom from lab management 14. Participation in decision making.				

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Harrold (1969)	1. Number of Professionals 2. Average length of R&D experience 3. Average time in laboratory 4. Average age of professionals 5. Number of professionals doing graduate work 6. Number of seminars held within laboratory 7. Number of personnel attending technical society meetings 8. Laboratory in-house budget 9. Average salary for civilian professionals.	Laboratory Records.	1. Number of papers and invention disclosures 2. Evaluation by 5 Army R&D executives of laboratory performance.	15 Army R&D laboratories	1. Statistical significance not reported. 2. Items 1-5 measured separately for military vs. civilian. 3. Correlations reported separately for each criterion. 4. Substantial Correlations (>0.3) were: a. Item 6 for both criteria b. Item 5 for civilians for both criteria c. Item 1 for both groups for criterion 1 d. Item 8 for both groups for criterion 1 e. Item 9 for criterion 1 f. Items 2 and 4 for military for criterion 2 (negative correlation).

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Hill (1970)	Participative vs. Autocratic Leadership	Interviews with members of the two groups.	Publication rate per member of the group.	2 groups of scientists (total of 25 scientists) in a division of a government research lab in Australia	1. At a point in time, the division leader took on an assistant leader and effectively broke the division into 2 groups. Criterion measurements were available for the next 8 years. 2. Statistical significance not reported due to low N. 3. The publication rate for the group under the old leader (participative) was approximately constant for 4-5 years after the change and then gradually declined. The publication rate for the group under the new autocratic leader dropped drastically in the 1st year and stayed low for 7 years. 4. Groups organized on basis of projects.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Hoffman Harburg and Maier (1962)	1. Strong vs. Weak Workers 2. Dominant vs. Considerate Foreman.	Experimentally arranged conditions.	Formulation and Adoption of a creative solution to Maier's Change of Work Procedure problem, vs. adoption of the old method or the proposed new method.	96 - 4 person groups of undergraduates.	1. Laboratory experiment. 2. The condition of strong vs. weak workers was significantly associated with the criterion, whereas dominant vs. considerate foreman was not. 3. The authors interpreted the findings that conflict of ideas(i.e. strong workers vs. foreman) led to creative solution.
Kallick (1964)	1. Informal new line organization 2. Formal old line organization 3. Cooperative departmental organization 4. Scientific non-profit organization	An Organizational Climate Questionnaire that measured the perceptions of individual subjects. The questionnaire was entitled the Job Environment Survey.	Self report of number of substantial contributions to: 1. new products 2. cost savings 3. product improvement.	668 engineers in many organizations.	1. Organizational variables resulted from factor analysis. 2. Factors 1 and 3 were significant in the positive direction. 3. Factors 2,4,5 and 6 were significant in the negative direction.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Kallick (1964) cont'd	5. Expediency 6. External to company environment.				4. Supervisory supportive, friendly relationships and rewards contingent on performance loaded heavily on 1. 5. Large, established organizations with good support services, loaded heavily on 2. 6. Team/Group activities loaded on 3. 7. Size loaded heavily on 5.
Keeler (1966)	1. Organizational Identification and loyalty. 2. Rewards Structure 3. Decision-Making Centralization 4. Research strategy (Individual vs. Group)	Questionnaires and interviews with individual subjects. Responses grouped by organization.	Laboratory Creativity Ranking consisting of: 1. Self rating of individual creative potential 2. Self rating of realization of individual creative potential 3. Rating of creative potential of coworkers	Scientists and Engineers in: 1. State Dept. of Public Health 2. A Not-for Profit laboratory	1. Statistical Significance not reported for any items-case study methodology used. 2. Organizational loyalty inversely related to creativity. 3. Traditional organizational rewards had limited effectiveness but

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Keeler (1966) cont'd	5. Communications 6. Empathy 7. Leadership.		4. Self rating of laboratory and lab work group creativity 5. Sources of innovational activity 6. Independent ratings 7. Specified Innovations.	3. Two military laboratories 4. A small industrial lab 5. Three university laboratories.	scientific recognition and increased research freedom were related to creativity. 4. Decision making centralization inversely related to creativity. 5. Group research more successful if research goals were well structured and vice versa. 6. Hi levels of communication associated with creativity. 7. Coworker empathy was associated with creativity. 8. Leadership by creative prestigious scientists (not administrators) associated with creativity.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Lawler, Hall and Oldham (1974)	1. Lab encouraged collaboration among researchers 2. Performance Reviews (Frequency and Relation to Compensation) 3. Professional Autonomy 4. Assignment generality 5. Informal budget account 6. Span of control 7. Size 8. Levels 9. Tall/Flat 10. Levels from Top.	Questionnaire completed by subjects and analysis of organization chart.	Self rating of technical and administrative performance.	117 Directors of research in 117 R&D Labs.	Variable (1) was significantly related to the criterion.
McCarrey and Edwards (1973)	1. Ease of Written Communication and Frequent Management Contact	Organizational Climate Questionnaire that assessed the perceptions of the individual subjects.	1. Productivity rank (peers) 2. Creativity rank (peers) 3. Departmental percentile standing	72 biological scientists in 4 Canadian Government	1. 1-11 were factor analysis titles of the 198 item Organizational Climate Inventory. 2. All the below relationships were

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
McCarrey and Edwards (1973) cont'd	2. Cool Autonomous Work Group Atmosphere 3. Lack of Customer Contact 4. Global Supervisory Planning and Role Diversity 5. Achievement Orientation (Balanced Local - Cosmopolitan Orientation) 6. Supervisory Flexibility (example regarding leave scheduling) 7. Technician under utilization, consultative, and goal setting activities 8. High management priorities orientation-local hierarchical orientation		4. Professional recognition score 5. Communications rank (peer) 6. Quality of publications rating (peers) 7. Originality of publications rating (peers) 8. Citation rate 9. Publications per year Factor Analysis of the 9 criteria yielded 3 factors: I. Creative Productivity (heavy loading of 1 and 2) II. Quality and Originality of Published Work III. Impact of Published Work on that of Others (heavy loading of 8 and 9).	Laboratories	statistically significant. a. 1 and 4 positive with I and 2 and 3 negative with I. b. 5 and 6 positive with II and 7 negative with II. c. 9 and 10 positive with III and 8 and 11 negative with III.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
McCarrey and Edwards (1973) cont'd	9. Low customer contact-effective project forecast. 10. Criticality regarding advancement (role of organizational politics) 11. High external controls regarding punctuality.				
Means (1966)	1. Utilitarian Self-Development 2. Supportive Supervisors and Peer Relationships 3. Perception of success 4. Professional and research orientation of supervision.	Kallick's (1964) Job Environment Survey (an Organizational Climate questionnaire that measured the perceptions of individual subjects).	Weighted average of self report of number of patents, papers, new products and processes.	457 mechanical engineers employed in a variety of R&D organizations.	1. 1-4 were factor analysis titles 2. 3 and 4 were significantly related to the criterion. 3. Factor 3 included: a. Adequate technicians, draftsmen, secretaries b. Stable environment c. long run goals more emphasized

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Means (1966) cont'd					than short run goals. 4. Factor 4 included: a. Supervisor published, contributed to patents, M.S. or Ph.D. b. Colleagues held advanced degrees c. After hours laboratory facilities for personal research. 5. No significant person x environment interaction was found. 6. No significant relationship of personal characteristics (as measured by a biodata form) and the criterion was found.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Meltzer and Salter (1962)	1. Size of organization (number of professionals) 2. Number of levels 3. Freedom 4. Chance to do a good job 5. Funds availability 6. Facilities Index 7. Ability Index 8. Academic/ Government/ Industry.	Questionnaire sent to individual subjects.	Self report of number of papers published in the past three years.	704 physiologists with doctorates employed at least 3 years in a variety of research organizations.	1. Variables 1 and 7 were not significant. 2. Variable 2 was significant-curvilinear (low point with medium number of levels-4 or 5). 3. Variables 3,4, 5,6 and 8 were all significant.
O'Brien and Ilgen (1968)	1. Leadership Style 2. Member Compatibility 3. Task Organization (Collaboration/Coordination).	1. Fiedler's LPC scales 2. Schutz's Compatibility FIRO scales 3. Absence or presence of collaboration and or coordination (experimentally arranged conditions).	Ratings by experimenters on plot originality, elaboration, plot structure, expressiveness, humor and suspence of short creative stories subjects wrote for each of 3 TAT pictures.	64 - 3 man groups of male undergraduates.	1. Laboratory experiment. 2. Task organization accounted for 29-30% of the variance in the ratings. 3. The organization with coordination but no collaboration scored highest

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
O'Brien and Ilgen (1968) cont'd					and the organization with collaboration but no coordination scored lowest.
Owens (1969)	1. Professional and Research Orientation of Supervision 2. Supportive Supervisory and peer relationships.	Kallick's (1964) Job Environment Survey (an Organizational Climate questionnaire that measured the perceptions of individual subjects).	Same as Means (1968)	961 engineers in various organizations.	1. Factor 1 same as Means (1968). 2. Factor 1 significantly related to the criterion. 3. No person x environment interaction was found.
Pelz (1956)	1. Frequency of Colleague Contact 2. Colleague Dissimilarity: a. Previous Employment b. Orientation (Science or Institutional). 3. Supervisor Leadership Methods:	Questionnaire completed by individual professionals.	Supervisor and Peer Rating of individuals scientific performance adjusted for: a. Ph.D. vs. non-Ph.D. b. Civil Service grade.	Number of professionals not reported. A large government research laboratory.	1. Statistical significance not reported. Results presented in graphical format. 2. Frequent (daily) contact with several dissimilar colleagues associated with high performance. 3. Frequent (daily) contact with super-

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Pelz (1956) cont'd	a. Frequency of contact b. Locus of Influence.				visor and independence associated with high performance 4. Frequent(daily) contact with 1 colleague of similar professional orientation associated with high performance.
Pelz and Andrews (1966)	1. Number of Decision-making sources(2) 2. Amount of Influence on Goal setter(2) 3. Major Sources of weight in goal setting (2) 4. Autonomy(4) 5. Frequency of Communication (2) 6. Number of colleagues in own group(2)	Questionnaire completed by individual scientist/ engineer.	1. Four separate individual measures(each for within the past 5 years and each converted to percentiles) were used: a. Supervisor and peer ranking of: i) Contribution to general technical or scientific knowledge in the field. ii) Over-all use-	1. Individual subjects were 1311 scientists and engineers in 11 laboratories: a. 641 in 5 industrial laboratories b. 144 professors	1. Results listed separately for 5 Groups: a. Ph.D.'s in Research Labs b. Ph.D.'s in Development Labs c. Non-Ph.D.'s in Research Labs d. Non-Ph.D.'s in Development Labs e. Non-Ph.D.'s in Ph.D. Dominated Labs. (2) Significant for some of 5 groups on some of 4 mea-

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Pelz and Andrews (1966) cont'd	7. Number of colleagues outside of own group but within organization(2) 8. Time spent contacting colleagues(2) 9. Diversity of activities (5) 10. Creative Ability (6) 11. Coordination (7) 12. Group Age (8) 13. Secretiveness within groups (9) 14. Secretiveness between groups (3) 15. Competition with colleagues (3) 16. Competition between groups (10).		fulness in helping the organization carry out its responsibilities. b. Self-report of: i) Number of papers or patents ii) Number of unpublished reports 2. The measures were adjusted for: a. Ph.D. vs. non-Ph.D. b. Research or Development c. Domination of Department by Ph.D.'s d. University, Government, or Industry e. Length of work experience f. Speed with which formal education completed. 3. Group score was mean of individual scores within group adjusted for:	from 1 university c. 526 scientists and engineers from 5 government laboratories 2. 83 groups of 2 to 25 members each a. 49 industry groups b. 34 government groups	sures. (3) Not significant (4) Significance not reported. (5) Many of the significant relationships were curvilinear (6) Measured by the Remote Associates Test - not significantly related to 4 criteria. (7) Significance not reported. Strong motivation or colleague stimulation correlated with performance under loose coordination. (8) Significant negative correlation (Group age defined as average number of years each member belonged). (9) Negative correlation for young groups and positive for old groups.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Pelz and Andrews (1966) cont'd			a. Individual's age b. Proportion of Ph.D.'s c. Departmental autonomy or coordination d. Government vs. industry.		(10) Significant for old groups.
Shepard (1956)	1. Group Age 2. Individual age.	1. Average number of months member had been in group 2. Average number of years member had been in R&D.	1. Management ratings: a. group creativity b. group productivity c. responsiveness to challenge 2. Colleague rating of group performance 3. Member self rating of group performance.	35 research groups ranging in size from 4-12 in 21 industrial labs.	1. Graphical presentation of the data showed a substantial negative relationship between group age and criteria 1 a, b, c and 3. 2. A substantial curvilinear effect between individual age and criteria 1 a, b, c and 2 was shown.
Smith (1970)	1. Consultation Structure: a. Decentralized	Divisional average of individual responses to questionnaire	1. Supervisor and colleague ranking: a. technical	15 divisions of an applied	Variables 2a and i were the only variables not significantly

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Smith (1970) cont'd	b. Horizontal c. Multi-Directional d. Formal e. Work Group Integrated f. Functional g. Extradivisional 2. Communication Channels: a. Meetings, all divisions b. Meetings, own division c. Meetings, other divisions d. Meetings, own work group e. Consultants, lectures f. Professional societies g. Contacts with supervisors h. Contacts within research team i. Contacts elsewhere in Company		contributions b. general usefulness to the laboratory of each division 2. Log of: a. Number of patents b. Number of published technical reports c. Number of unpublished papers (a,b,c for the last 5 years). 3. The above measures were adjusted for: a. Number of Ph.D.'s in division b. Average length of time each member was in the division c. Highest degree earned.	industrial research laboratory.	correlated with some of the criteria.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Smith (1970) cont'd	j. Contacts outside company k. Internal Communication memos l. External publications m. Literature search by information service 3. Influence Structure: a. Decentralized Influence b. Shared Influence.				
Smith (1971)	1. Group Heterogeneity: a. Achievement values b. Organizational opportunities c. Problem-solving approaches	Questionnaire completed by individual scientists and engineers: 1. Variance across group members 2. Difference between group	1. Group means of member scores: a. Supervisor and peer ranking (paired comparison) i) Technical Contribution ii) General Usefulness to laboratory	49 groups (ranging in size from 3-11) with 418 scientists and en-	1. Data segregated for young (3 years and less) and old groups (more than 3 years). 2. More significant findings for young groups when relating heterogeneity to

TABLE IV - continued

AUTHOR	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Smith (1971) cont'd	d. Technical functions 2. Leader-Member Heterogeneity: same as a through d above 3. Supervisory Functions: a. Technical i) Knowledge ii) Original Ideas b. Facilitative i) Enthusiasm ii) Neutral Sounding Board iii) Encouragement.	leader score and group average.	b. Self report: (past 5 years) i) Logarithm of patents ii) Logarithm of technical papers 2. Above scores corrected for: a. Highest degree b. Time in division c. Ratio of Ph.D.'s in division d. Emphasis on coordination e. Emphasis on research.	gineers in an applied industrial research laboratory	performance were noted. 3. Organizational Variables (1c) and (3a ii) were the only variables not statistically significant for some groups on some criterion.
Stone (1971)	1. Mode of organization (Project Team vs. Specialization) 2. Feedback Level (Individual vs. Group).	Experimentally determined conditions: Members shared all 3 rules vs. each member was given only 1 rule and was to advocate using the 1 rule.	Judge rating of creativity of words constructed by groups from letters.	24 3-man groups of undergraduates.	1. Lab Experiment. 2. In the project team mode, members were instructed to cooperate with one another. 3. Neither mode of organization or feedback level

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Stone (1971) cont'd					was significantly related to the criterion.
Vollmer (1963)	Incentives Related to: 1. Nature of Work 2. Resources 3. Rewards for work 4. Career development.	Interviews and questionnaires administered to individual subjects.	Number of publications based on research conducted in the organization.	271 research personnel in a large independent research organization.	1. Statistical significance not reported. 2. Opportunity to do Basic Research, opportunity to be a project leader and freedom of choice in research assignments under 1, and recognition for research under 3 were substantially related to the criterion. 3. Frequency of non-formalized research was also substantially related to the criterion.

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Wallmark and Sellerberg (1966)	Team Size	Questionnaire sent to authors in teams asking for number of graduate engineers or researchers in the organization working on laser problems.	Net Citations (Number of times publications originating within a research team were cited by publications originating in other research teams in 6 journals publishing articles on lasers).	22 teams in 22 organizations (industrial, academic and military) engaged in laser research.	1. Statistical significance not reported. 2. Plot of number of Net Citations vs. Number of authors showed a strongly positive relationship. 3. Author noted a slightly positive relationship for number of net citations per author vs. number of authors in the team. 4. Replot of data showed slight negative relationship for number of citations per team member vs. team size.
Ziller, Behringer and Goodchilds (1962)	1. Group Stability (Open vs. Closed) 2. Success/ Failure Interaction	1. Replacement, Addition or Removal of a member vs. control stable groups.	1. Number of cartoon captions group wrote for a captionless cartoon.	64 3-man groups of undergraduates	1. Lab Experiment. 2. Open groups scored significantly higher than did closed groups on both

TABLE IV - continued

AUTHORS	ORGANIZATIONAL VARIABLES	ORGANIZATIONAL VARIABLES MEASURE	CRITERIA MEASURES	SUBJECTS	FINDINGS
Ziller, Behringer and Goodchilds (1962) cont'd	with Group Stability.	2. Experimenters informed groups that they had succeeded/failed on an early task.	2. Judge ratings of humor on captions.		criteria. 3. No significant interaction of items 1 and 2 was found.

This variance requires detailed exploration in the criterion section before selection of a measure for use herein.

In spite of the variety of both organizational and criteria measures employed and the resulting difficulty of comparison of studies, some variables were recurring (at least in title).

2.2.2 Categorization of Variables

Table V recategorizes the organizational variables according to approximate commonality. Four categories of variables are presented: group, supervisor, other organizational and statistical control. Some variables are in more than one category due to their multiple applicability or ambiguity.

TABLE V

CATEGORIZATION OF ORGANIZATIONAL VARIABLES

A) GROUP VARIABLES

1. * Frequency of communication - Pelz and Andrews (1966)
   * Frequency of colleague contact - Pelz (1956)
   Communication channels - Smith (1970)
   * a. Meetings - own work group
   * b. Contacts within research team
   * Communication (high levels) - Keeler (1966)
   * Contact - Farris (1969)
   * Time spent contacting colleagues - Pelz and Andrews (1966)
   * Collaboration/coordination - O'Brien and Ilgen (1968)
   * Collaboration among researchers - Lawler, Hall and Oldham (1974)
   * Consultation (Work group integrated) - Smith (1970)

* Statistically significant, or substantial if significance not reported.

TABLE V - continued

* Interpersonal collaboration (Knowledge Based Risk Taking) - Aram, Morgan and Esbeck (1971)
* Group research - Keeler (1966)
* Cooperative departmental organization (Group/Team activities) - Kallick (1964)

2. * Group age - Pelz and Andrews (1966)
   * Group stability (Open/Closed) - Zillер, Behringer and Goodchilds (1962)
   * Group age - Shepard (1956)

3. * Colleagues held advanced degrees - Owens (1969)
   * Colleagues held advanced degrees - Means (1966)

4. * Colleague dissimilarity (Previous employment, science/ organizational orientation - Pelz (1956)
   Group heterogeneity - Smith (1971)
   * a. Achievement values
   * b. Organizational opportunities
   * c. Technical functions
   Technical conflict peers - Evan (1965)

5. * Number of colleagues in own group - Pelz and Andrews (1966)
   * Team size - Wallmark and Sellerberg (1966)
   Group size - Gibb (1951)

6. Supportive peer relationships - Owens (1969)
   Supportive peer relationships - Means (1966)
   Interpersonal collaboration - Aram, Morgan and Esbeck (1971)
   a. Support and integration
   b. Open, authentic communications
   Cognitive sensitivity of group - Andrews and Gordon (1970-III)
   * Coworker empathy - Keeler (1966)
   Member compatibility - O'Brien and Ilgen (1968)
   Interpersonal competence - Connor (1974)
   Interpersonal conflict peers - Evan (1965)

7. * Threat reduction - Gibb (1951)

B) SUPERVISOR VARIABLES

1. * Technical skills - Andrews and Farris (1967)
   * Technical Knowledge - Smith (1971)
   * Supervisor published, contributed to patents, M.S. or Ph.D. - Owens (1969)

TABLE V - continued

* Supervisor published, contributed to patents, M.S. or Ph.D. - Means (1966)
* Creative prestigious scientists - Keeler (1966)
Supervisory original ideas - Smith (1971)

2. * Frequency of contact with supervisor - Pelz (1956)
* Contacts with supervisors - Smith (1970)
* Frequent management contact - McCarrey and Edwards (1973)

3. * Participatory/supervisory leadership - Anderson and Fiedler (1964)
* Influence(individual) - Farris (1969)
* Participative/autocratic leadership - Hill (1970)
* Shared influence - Smith (1970)
Leadership style (consultation) - Andrews and Farris (1967)
* Strong/weak workers - Hoffman, Harburg and Maier (1962)

4. * Participation in determination of projects - Harrison (1974)
Individual responsibility for initiating new activities- Andrews and Gordon (1970-I)
* Participation in establishment of management objectives - Harrison (1974)
* Supervisory influence on goals - Andrews and Farris (1967)
* Amount of (individual's) influence on goal setter - Pelz and Andrews (1966)
* Major sources of weight in goal setting - Pelz and Andrews (1966)

5. * Individual influence in decision making - Andrews and Gordon (1970-I)
* Participation in decision making - Harrison (1974)
* Number of decision making sources - Pelz and Andrews (1966)

6. * Critical evaluation - Andrews and Farris (1967)
* Neutral sounding board - Smith (1971)
* Visibility of consequences - Gordon and Marquis (1966)

7. * Superior non-interference - Andrews and Gordon (1970-I)
Freedom from laboratory management - Harrison (1974)
Leadership style (freedom) - Andrews and Farris (1967)
* Freedom (from superior) - Gordon and Marquis (1966)
* Freedom - Meltzer and Salter (1962)
Professional autonomy - Lawler, Hall and Oldham (1974)
* High external controls regarding punctuality/supervisory flexibility - McCarrey and Edwards (1973)

TABLE V - continued

8. * Human relations functions - Andrews and Farris (1967)
   * Relationship/rapport with superior - Harrison (1974)
   Supportive supervisory relationship - Owens (1969)
   Supportive supervisory relationship - Means (1966)
   Leadership style (LPC) - Fiedler and Barron (1967)
   Leadership style (LPC) - O'Brien and Ilgen (1968)
   * Supportive friendly supervisory relationships (Informal new line organization) - Kallick (1964)
   Dominant/considerate foreman - Hoffman, Harburg and Maier (1962)
   Interpersonal conflict supervisor-subordinate - Evan (1965)

9. Leader-member heterogeneity - Smith (1971)
   * a. Achievement values
   * b. Organizational opportunities
   * c. Problem-solving approaches
   * d. Technical functions
   Technical conflict supervisor-subordinate - Evan (1965)

10. * Administrative functions - Andrews and Farris (1967)
    * Global supervisory planning - McCarrey and Edwards (1973)

11. * Enthusiasm - Smith (1971)
    * Encouragement - Smith (1971)

12. * Time pressure - Andrews and Farris (1972)
    Time pressure - Hall and Lawler (1970)

13. * Quality pressure - Hall and Lawler (1970)
    * Chance to do a good job - Meltzer and Salter (1962)

14. * Financial goals pressure - Hall and Lawler (1970)
    * Frequency of non-formalized research - Vollmer (1963)

15. * Reward structure - Keeler (1966)
    * Rewards contingent on performance/Informal new line organization - Kallick (1964)
    * Criticality regarding advancement (role of organizational politics) - McCarrey and Edwards (1973)
    * Recognition for research - Vollmer (1963)
    * Opportunity to do basic research - Vollmer (1963)
    * Opportunity to be a project leader - Vollmer (1963)
    * Freedom of choice in research assignments - Vollmer (1963)
    Incentives related to resources and career development - Vollmer (1963)

TABLE V - continued

C) OTHER ORGANIZATIONAL VARIABLES

1. * Decision making centralization - Keeler (1966)
   * Decentralized influence - Smith (1970)

2. * Organizational loyalty - Keeler (1966)
   * Scientific non-profit organization - Kallick (1964)
   * Balanced local-cosmopolitan orientation - McCarrey and Edwards (1973)

3. * General organizational climate- Ellison, et al. (1968)
   * Work group, branch, division, department and laboratory in general - Ellison,et al. (1968)

4. * Freedom to publish - Harrison (1974)

5. * Number of seminars within laboratory - Harrold (1969)
   * Meetings-own division - Smith (1970)
   * Meetings-other division - Smith (1970)
   * Internal communication memos - Smith (1970)
   Contacts elsewhere in company - Smith (1970)
   Meetings- all divisions - Smith (1970)
   * Frequency of colleague contact - Pelz (1956)
   Bottom-up and top-down communication - Harrison (1974)
   * Consultation structure (decentralized, horizontal, multi-directional, formal, functional, extradivisional) - Smith (1970)
   * Time spent contacting colleagues - Pelz and Andrews (1966)

6. * Communication channels (professional societies) - Smith (1970)
   Number of personnel attending technical society meetings - Harrold (1969)

7. * Salary - Farris (1969)
   * Average salary - Harrold (1969)

8. * Diversity of activities - Farris (1969)
   * Diversity of activities - Pelz and Andrews (1966)
   Wide range of projects - Hall and Lawler (1970)
   Assignment generality - Lawler, Hall and Oldham (1974)
   * Role diversity (administrative, consultative and goal setting activities) - McCarrey and Edwards (1973)

9. * Direct customer responsibility - Hall and Lawler (1970)
   * Lack of customer contact - McCarrey and Edwards (1973)

10. * Number of professionals - Harrold (1969)
    * Laboratory budget - Harrold (1969)
    * Number of subordinates - Farris (1969)

TABLE V - continued

* Expediency/size - Kallick (1964)
Size - Lawler, Hall and Oldham (1974)
Size of organization(number of professionals) - Meltzer and Salter (1962)
* Number of colleagues outside own group but within organization - Pelz and Andrews (1966)

11. * After hour laboratory facilities for personal research - Owens (1969)
* After hour laboratory facilities for personal research - Means (1966)
* Facilities index - Meltzer and Salter (1962)
* Support services(Formal old line organization) - Kallick (1964)
* Literature search by information service - Smith (1970)
* Technician underutilization - McCarrey and Edwards (1973)
* Adequate technicians, draftsmen, secretaries - Means (1966)

12. * Competition between groups - Pelz and Andrews (1966)
Competition with colleagues - Pelz and Andrews (1966)

13. * Communication channels(consultants, lectures) - Smith (1970)
* Communication channels(contacts outside company) - Smith (1970)
* Communication channels(external publications) - Smith (1970)

14. Funds available - Meltzer and Salter (1962)

15. Percent of time spent on work approved in advance by management - Harrison (1974)
Definition of duties and responsibilities - Harrison (1974)

16. Job Challenge - Hall and Lawler (1970)

17. Independent budget - Hall and Lawler (1970)
Informal budget account - Lawler, Hall and Oldham (1974)

18. Mode of organization (Project team/specialization) - Stone (1971)

19. Feedback level (Individual/group) - Stone (1971)

20. Secretiveness between groups - Pelz and Andrews (1966)

21. * Number of levels - Meltzer and Salter (1962)
Levels - Lawler, Hall and Oldham (1974)

TABLE V - continued

22. Levels from top - Lawler, Hall and Oldham (1974)

23. Span of control - Lawler, Hall and Oldham (1974)

24. Tall/flat - Lawler, Hall and Oldham (1974)

25. Performance reviews - Lawler, Hall and Oldham (1974)

26. Company paid for/supported training, education and professional activities - Means (1966)

27.* Stable environment - Means (1966)

28.* Long run goals more emphasized than short run goals - Means (1966)

D) STATISTICAL CONTROL VARIABLES

1. Length of R&D experience - Harrold (1969)
   Experience - Andrews and Farris (1967 and 1972)
   Length of work experience - Pelz and Andrews (1966)

2. Time in laboratory - Harrold (1969)
   Time with laboratory - Farris (1969)
   Seniority - Andrews and Farris (1967 and 1972)

3. Time in division - Smith (1971)
   Division age - Smith (1970)

4. Time on major project - Ellison, et al. (1968)

5. Formal training - Andrews and Farris (1967 and 1972)
   Education - Ellison, et al. (1968)
   Highest degree earned - Farris (1969)
   Ph.D. vs. non-Ph.D. - Pelz (1956)
   Ph.D. vs. non-Ph.D. - Pelz and Andrews (1966)
   Highest degree earned - Smith (1970)
   Highest degree earned - Smith (1971)

6. Research or development - Pelz and Andrews (1966)
   Type of work(basic research, applied research, operational) - Ellison, et al. (1968)
   Emphasis on research - Smith (1971)

7. GS grade - Pelz (1956)

8. Scientist/engineer - Connor and Scott (1974)

9. Military/civilian - Harrold (1969)

TABLE V - continued

10. Time since receiving highest degree - Farris (1969)

11. Speed with which formal education completed - Pelz and Andrews (1966)

12. University, government, industry - Pelz and Andrews (1966)
Academic, government, industry - Meltzer and Salter (1962)

13. Emphasis on coordination - Smith (1971)

14. Age of professionals - Harrold (1969)
* Age - Shepard (1956)

15.* Number of professionals doing graduate work - Harrold (1969)

As indicated previously, this categorization process was employed to suggest a tentative list of variables. The results of Table V along with the theorizing of the writer and chairman of his dissertation committee resulted in the list of variables that this research effort explored. The final list is described in Table VI.

2.2.3 Included Variables

Table VI contains the list of the 41 organizational variables suggested for study in this research. The variables are grouped according to the expected source of information. Data on variables numbered 1 through 27 were expected from the individual scientist/engineer within the groups, on variables numbered 28 through 35 from the group leader, and on variables 36 through 41 from the laboratories. More is said on the sources in the measurement section (4.1).

TABLE VI

INCLUDED ORGANIZATIONAL VARIABLES

VARIABLE NUMBER	VARIABLE TITLE
1.	Age
2.	Educational level
3.	Group heterogeneity - technical discipline
4.	Current grade
5.	Scientist/engineer ratio
6.	Length of scientific/engineering experience
7.	Length of Federal Government Employment as a scientist/engineer
8.	Length of group membership
9.	Per cent of time in nontechnical activities
10.	Frequency of attendance at professional society meetings
11.	Frequency of communication with other scientists/ engineers within group on technical matters
12.	Frequency of communication with other scientists/ engineers outside group on technical matters
13.	Frequency of communication with group leader on technical matters
14.	Innovation pressure
15.	Quantity pressure
16.	Time pressure
17.	Air Force relevancy pressure
18.	Group leader professional competence
19.	Extent participation - goal setting

TABLE VI - continued

VARIABLE NUMBER	VARIABLE TITLE
20.	Extent participation- decision making
21.	Extent of group leader's empathy
22.	Rewards for innovation
23.	Rewards for quantity of output
24.	Extent to which group leader evaluates work
25.	Mission stability
26.	Freedom/autonomy from group leader
27.	Type of work(research, development, support)/group
28.	Group leader age
29.	Group leader educational level
30.	Group - group leader homogeneity- technical discipline
31.	Time in group leader position
32.	Turnover
33.	Group age
34.	Budget trend: dollars/group
35.	Budget trend: personnel/group
36.	Number of projects(Work units)*/group
37.	Group size(number of scientists/engineers)
38.	Laboratory size(number of scientists/engineers)
39.	Laboratory
40.	Division
41.	Branch

* A Work unit was the smallest piece or "chunk" of identifiable work in a group.

Throughout the remainder of this study, the terms group and group leader are used to refer to the lowest level formal organizational unit or work group, and the formal leader or immediate supervisor of the group, respectively.

Variables were included in the list by use of three criteria: most consistently appearing with significant/substantial relationships in the empirical studies (Tables IV and V); the postulations of the writer and the chairman of his dissertation committee; and ease of measurement.

The construction of Table VI satisfied the first objective for this research (Section 1.3), that of identifying organizational variables that appeared to be promising as correlates of innovation and productivity of scientists and engineers.

2.3 The Criterion Problem

One of the most complex issues that a researcher must face in the area of innovation is the criterion problem , i.e. what is, and just as importantly, how does one measure innovation. Emphasizing the importance of the problem , Taylor and Holland (1964) remarked: "The authors are convinced that there is no more crucial problem in creativity than the criterion problem." (p.31)

The difference between measures of innovation used in the literature is very large. A perusal of the various

criterion measures employed by the studies summarized in Table IV underscores the divergence of the measures. They range from objective measures such as number of patents, patent applications, unpublished reports, publications, and awards, to subjective measures such as evaluations by supervisors, peers, judges and self, and also included various combinations of the above.

Apparently, the different measures were not all measuring the same construct, or at least, not the same dimensions of a common construct. Taylor, Smith, Ghiselin and Ellison (1961) factor analyzed data on 52 different criteria and produced 15 dimensions. Various dimensions or combinations of dimensions were examined in different studies, yet almost all received the same label of innovation or creativity. Such differences in criterion measurement make it difficult to compare the results of different studies that researched similar predictors. They also raise questions about the validity of the diverse measures.

Perhaps if agreement is reached at the conceptual definitional level, progress can be made at the operational measurement level.

One way to start a definition of innovation is to limit the term by defining what it is not.

2.3.1 Innovation NOT Creativity

Innovation and creativity are two terms that were

often used interchangeably in the literature. Such a lack of discrimination frequently leads to confusion and controversy. Are the terms synonymous? Do they refer to products, processes or abilities?

Webster's Dictionary (1971) did more to segregate the terms than much of the current literature. It defined creativity as "the ability to create" (p.195) and innovation as "a new idea, method, or device." (p.436)

Pelz and Andrews (1966) made an effort to distinguish between ability and products, but in so doing somewhat clouded the issue. They " distinguish creative ability (the potential) from creativity (a characteristic of the product)." (p.155)

Since this study was not concerned with abilities or characteristics of people, the term creativity was outside the scope of this research effort and was not used herein. Innovation, viewed as a characteristic or quality of output, was the concern of this study.

Tentatively accepting the characteristic of newness or originality, the question of its meaning arises.

2.3.2 Originality

Exactly what is meant by originality?

In trying to resolve the question, Steger (1975) referred to innovative researchers as:

> "Those individuals who have(and do) made (make) discrete jumps in knowledge, theory

> technique or product that was not readily predictable before the fact, given the scientific or engineering state of the art." (p.23)

He added a remark on viewing innovation as discontinuous (i.e. discrete jumps) whereas non-innovative or productive work was just a continuous extension in a somewhat predictable fashion. Steger also noted:

> "Most scientists and engineers readily recognize this as analogous to a discontinuous versus continuous function and therefore were able to translate it into professional innovation very easily." (p.2)

Andrews and Farris (1972) took a similar position by defining productiveness as:

> "...the extent the man's work had increased knowledge along established lines of research or development or as extensions or refinements of previous lines." (p.188) (Emphasis added.)

In other words, innovation involves a discrete jump or a discontinunity from the present state that was not readily predictable before the fact.

But, is originality a necessary and sufficient condition for output to be classed as innovative?

2.3.3 Original AND Useful

One additional characteristic must be specified, in addition to the originality of output, in order to distinguish the output of professional scientists and engineers from that of mental patients. Steger (1975) asked: "How do

we differentiate innovative from just bizarre thoughts or creations?" (p.8) Institutionalized people have presented novel solutions to problems, yet they were frequently absurd. Addition of the characteristic of usefulness should distinguish the output of professional researchers from that of the other group.

Brogden and Sprecher (1964) preferred the word "value" and wrote:

> "Almost all workers agree that one important characteristic of the creative scientist is the originality of his product; most would add that the value of his product, variously conceived, is also important." (p.156)

Pelz and Andrews (1966) took the same position (in spite of their use of the term creativity). They wrote:

> "When we say a person's work shows high creativity, it means that others have found his performance both original and in some way useful. Originality is simply the quality of being different or unusual." (p.154)

The addition of the useful limitation is not an obscure one. In addition to the above three cited publications, Kallick (1964), Keeler (1966), McPherson(1963) and Steiner (1965) have added it in their discussions of what constitutes innovation. Many studies in Table IV have included it in their measures of innovation (either explicitly in their instruction to raters/judges or implicitly by assuming that patent offices and editorial boards included usefulness in their evaluations.)

By useful is meant adding to the fund of knowledge or being workable if capable of demonstration and test. One sticky question with the useful standard remains. What qualification can be used on output that apparently conflicts with existing knowledge and is not yet capable of demonstration and test? For example, Einstein's theory concerning the transferability of energy and matter apparently conflicted with existing knowledge and was not demonstrated workable in a nuclear device for decades after he proposed the theory.

In an answer to the question, Steger (1975) added the restriction: "...this innovation must be repeatable by other researchers." (p.9) Thus, if the logic, theory or methodology behind the original output is replicable by colleagues, even though it apparently conflicts with existing knowledge and is years away from demonstration and test, it is useful and thus an innovation.

Replicability should result in inclusion of output that was well thought out, logical, and internally consistent, even though perhaps departing from current knowledge at one point. It should also cause the exclusion of solutions/theories whose underlying methodology was questionable or vague.

To recapitulate, the definition of innovation accepted thus far is output that is original and useful (i.e. adds to the fund of knowledge, or is workable or repeatable).

2.3.4 Original and Useful to Whom

To whom must the output be innovative? In other words, who is the referent?

Acceptance of the individual as the referent, i.e. output which is original and useful to the individual is an innovation, leads to confusion with the terms growth and learning and adds little in the classificatory scheme. For example, the writer's infant daughter just learned a new and useful function for her fingers. Besides sucking on them, she can use them to hold a bottle. For her, it is a new and useful technique, to the rest of the world it is rather mundane and adds nothing. Obviously, the referent is external to the individual.

Acceptance of the employing organization as the referent also leads to problems. One can think of examples of output of scientists and engineers in R&D Laboratories which, in spite of being highly original and useful, because of organizational politics, inertia, prior commitments, failure to recognize sunk costs, austere budgets, etc., were not used by the parent organization. Usefulness to the parent organization in the sense of profitability or acceptance into the operational inventory (as in the military) could negate output consisting of knowledge or theory that is years from the point of demonstration, test, and production. Thus, usefulness or acceptance by the parent organization places artificial bounds on the output.

The focus of this study was on scientists and engineers working as professionals in specilaized technical disciplines. Therefore, having rejected the individual and the organization as the referent, the conclusion was reached that the output must be original and useful to the profession or technical discipline, in essence one's professional peers.

One more restriction needs to be added on output.

2.3.5 Output

What is to be included in the list of output of scientists and engineers?

At first glance, this may appear to be a rather mundane question that could be answered by merely observing what tasks they performed and what was the result. Reflection, however, reveals an interesting issue, both from the conceptual and operational levels with regard to ideas and thoughts.

One of the most extensive listings of the products of researchers was a list provided by McPherson (1963). He wrote:

> "This paper proposes that an examination of the products of research men is one of the best sources for ultimate criteria. What are some of the creative products produced by a scientist? ... patents, patent disclosures, publications, unpublished research reports, unprinted oral presentations, improved processes, new instruments, new analytical methods, ideas, new products and new compounds." (p.24)

In a widely cited empirical study that related the output of scientists and engineers to a variety of conditions, Pelz and Andrews (1966) included in the list of output of scientific products:

> "...(a) patents or patent applications, (b) published papers, (c) books, and (d) umpublished technical manuscripts, reports or formal talks." (p.271)

McPherson failed to recognize the difficulties in measuring ideas. Apparently, Pelz and Andrews recognized them since they did not include ideas in their list.

In a classic text on measurement, Torgerson (1958) stresses the importance of defining properties such that they are measurable. He wrote:

> "...the advantages of defining (a property) in terms of measurement, as contrasted with a purely classificatory definition, accrue both in the descriptive and in the explanatory functions of science." (p.9)

Realizing that this research effort attempted more than classification, output must be defined such that it is measurable. But how does one measure the innovation of intangibles, like ideas or thoughts? If at a minimum, a researcher did not write up his ideas/theories, or formally communicate them to others in oral presentations (never mind translate them into a product/process), how can the originality and usefulness (especially repeatability of logic and methodology) be assessed? Noting the importance of this stage, Keeler (1966) wrote:

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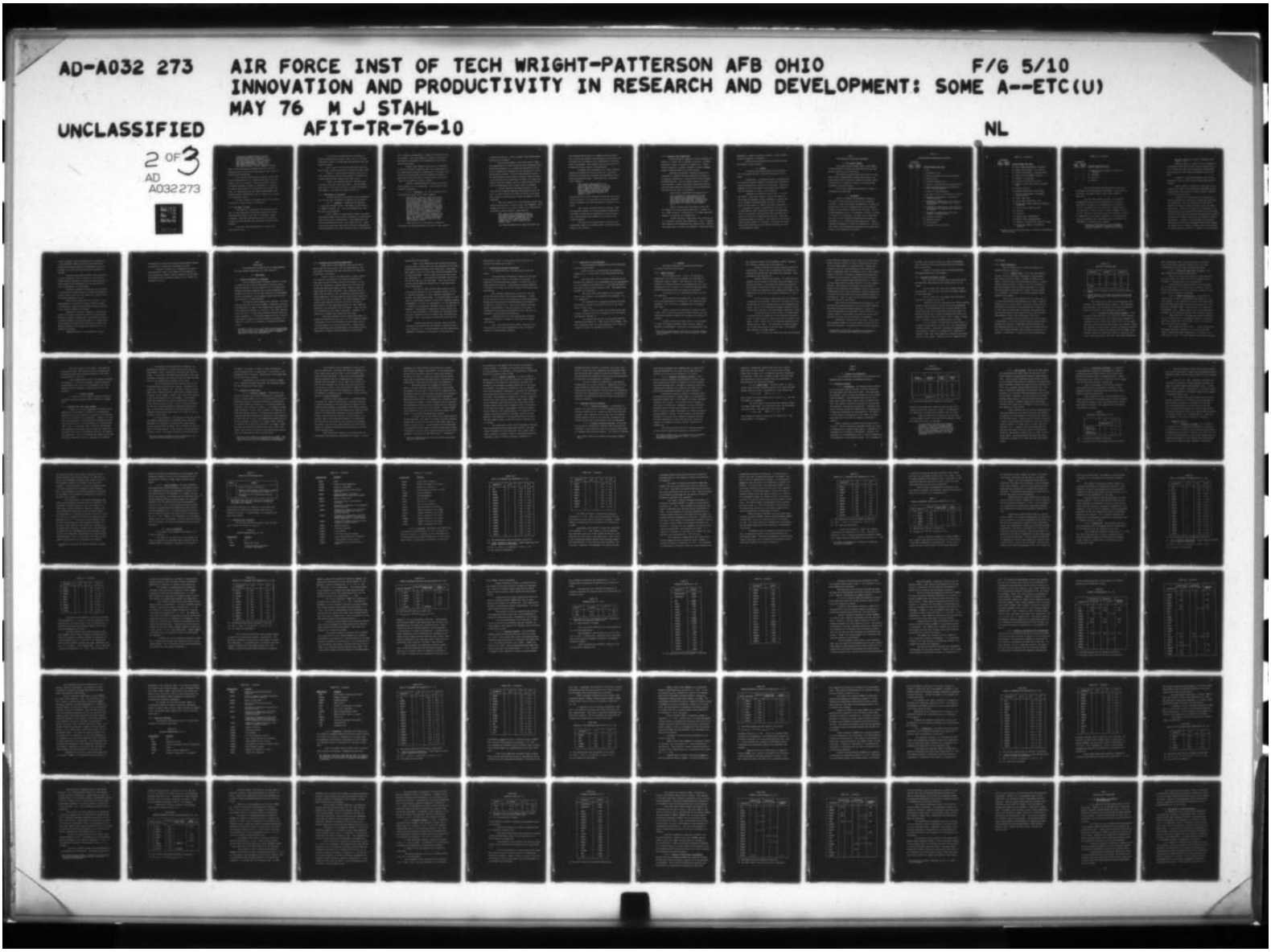

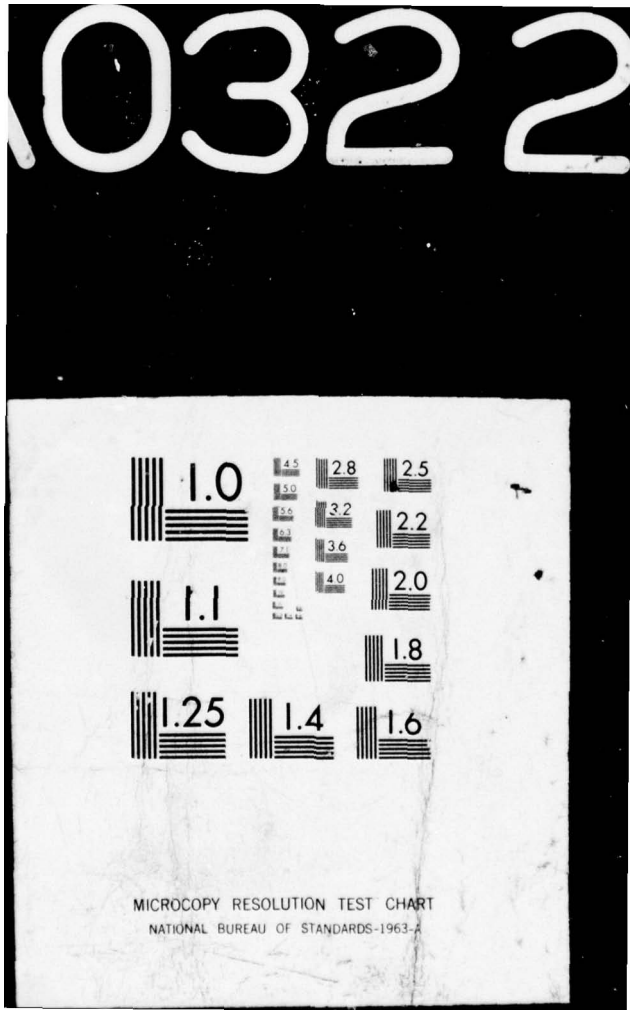
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

> "The stage of communication of results is important because it implicitly narrows the definition of creativity to include only those products which eventually take some visible form. This makes the measurement of creativity possible and also imposes some standard of utility on the creative product." (p.26) (Emphasis added.)

Steger (1975) specifically excluded "ideas that never got operationalized" (p.23) in his instructions to the raters of innovation and productivity.

Thus, due to the measurement problems, effort that was not operationalized (e.g. ideas and thoughts) is not included in the list of output. Output is defined as: (a) new or improved processes, products or techniques; (b) patents and patent applications; (c) published technical papers and books; (d) unpublished technical reports/memorandums, manuscripts and oral presentations; and (e) requests for proposals (for contractual effort).

For how long must one measure output of researchers to achieve a reliable measure of innovation?

2.3.6 Time Span of Output

There may be a considerable lag between the time that a scientist/engineer had started a project and it was translated into output in the form of a document, product or process. There may be extensive periods with little or no output and then periods with considerable output bunched together.

The above implies measurement of output over a long period of time.

It must also be recognized that the memory of fellow professionals is limited. Thus, there is a finite time span of output over which they can accurately rate the output of others.

Also, some of the fellow professionals have only been in their current positions for a relatively short time.

Finally, it was desired to measure output over a short enough time period that relationships to measures of current organizational variables had some meaning.

Wishing to accomodate the above considerations, a period of two years output was chosen. Periods ranging from a year to five years (as well as unspecified periods) were common in the empirical studies of Table IV.

2.3.7 Measurement of Innovation

Various measures of innovation could be subdivided into the two broad categories of objective and subjective.

2.3.7.1 Objective. Frequently used measures of innovation include counts of the number of publications or number of patents, etc. Two major problems arise with the use of such measures.

First, numbers of publications, patents and patent applications seemed to be largely a function of organizational policy and security considerations. Some organizations actively encouraged publication, while others did not. Needless to say, there were some areas in Air Force Laboratories where publication in the open literature was not even possible

due to security considerations. Similar considerations arise with patents. Also, the incentive to patent in the government sector is diminished since technically the government retained the rights.

Second, there seemed to be an implicit assumption in the use of objective measures that the innovativeness of all publications was equal or likewise with all patents, etc. Given the variance between editors concerning standards of publication and the variance in innovativeness of patented items, this assumption is hardly tenable.

Perhaps a weighted measure of numbers of publications, patents, etc. is appropriate. But weighting implies subjective evaluation.

2.3.7.2 Subjective. In a text devoted solely to evaluating R&D output, Quinn (1959) remarked:

> "Publications, patents, patent disclosures, etc. are included in the total set of criteria used in appraising research quality. But they can by no means be used as mathematical measures. Judging the quality of research performance is necessarily a subjective process. Mathematical devices maybe used as checks on subjective judgements but not as substitutes for them. Like appraisals of art, the ultimate recognition and application of the criteria used for judging research quality can occur only in the minds of the individuals appraising the work. The validity of their judgement depends upon their own technical expertness and/or on their own past experience with similar work." (p.193)

Given that one is in the realm of subjective evaluation, the question becomes one of who is best qualified

to rate the innovation. Various answers tried include judges, superiors and colleagues.

Judge ratings seemed to work fairly well in laboratory experiments for highly structured tasks requiring little specialized knowledge (e.g. judging the originality of solutions to hypothetical problems, or the originality of stories written about pictures). But one could seriously question the qualifications and abilities of external judges to evaluate the originality and usefulness of output in a highly specialized technical research area that required years of education and experience just to reach a level of adequacy.

It would seem that only people working in that field have the technical expertise and familiarity with the work to validly evaluate the output of others in the field. Thus, supervisor and colleague evaluations seemed to be two candidates.

There does appear to be some drawbacks however with supervisor evaluations. Erickson, Gantz and Stephenson (1970) reported the results of a study in which they collected data on several criteria measures. They remarked:

> "The other criteria examined, number of publications, only discriminates between the groups defined by supervisor ratings. This would tend to indicate that the supervisors may be unduly influenced by productivity in their ratings of creativity." (p.5)

One could hypothesize that supervisors,being one

level removed from the work in a dynamic research environment and with less exposure and familiarity with the work and the output than colleagues, due to administrative and managerial time demands, could readily count quantities but not adequately evaluate quality or innovativeness.

It appears that colleagues, due to their technical expertise and familiarity with the work are in the best position to evaluate the originality and usefulness of scientific/engineering output. Reinforcing this view Connor (1974) remarked:

> "The eventual determination of the significance and importance of a scientists work must be made by those best able to judge that work-his scientific peers; indeed it seems that collegial recognition provides the single best index of a scientists research competence." (p.2)

Assuming that two or more colleague evaluations were obtained per individual, the reliability or interjudge agreement could be examined as an added advantage of colleague evaluations.

Thus, having discarded objective measures, judge and supervisor ratings, and having identified professional colleagues as being the best qualified to evaluate innovation, peer evaluation was selected in this study as the criterion measure.

The issue of the relationship of innovation and productivity needs to be discussed before leaving the development of the criterion.

2.3.8 Innovation and Productivity

Innovation may be viewed as a quality dimension of output (i.e. output that is original and useful). Another dimension of output is quantity or productivity. Productivity is defined as quantity or amount of output, without regard to innovativeness or any other quality.

Recalling the section on objective measures of innovation, it appears that many studies which claimed to be measuring innovation or creativity were actually measuring productivity by merely recording quantity of output. At the minimum, it makes inter-study comparisons difficult since some were measuring innovation and some productivity (and most had the label of creativity) !

Taylor (1964) highlighted the problem thusly:

> "It is necessary to distinguish creativity from productivity, since productivity implies quantity and creativity implies high quality of a particular kind. Research findings suggest that creativity and productivity overlap to at least a limited degree." (p.6)

Taylor's comment about the degree to which the two dimensions overlap deserves exploration. Ellison, et al., (1968) obtained a correlation of .70 between supervisor rankings of creativity and productivity.

Andrews and Farris (1972) also found a correlation of .70 between innovation and productivity. Thus, it appears that innovation and productivity do indeed overlap. However, the overlap does not justify the labeling of some productivity

measures (e.g. number of patents or papers) in other research studies as measures of innovation.

Innovation and productivity were examined as separate outputs in this research.

2.4 Summary

A review of the organizational climate construct led to the conclusion that it was not applicable for this study.

Subsequently, a literature review of relevant empirical studies revealed a number of organizational variables as possible candidates for inclusion in this study. Review and appraisal of the list yielded a much smaller list (Table VI) which was suggested for study in this research.

Innovation was defined as output that is original and useful. Originality refers to output that makes discrete jumps in knowledge, theory, technique or product that was not readily predictable before the fact. Usefulness means that the output: (a) adds to the fund of knowledge, or (b) is workable if capable of demonstration and test, or (c) is replicable by other researchers in logic and methodology, even if it apparently conflicts with other knowledge and is years from the point of demonstration and test. Only operationalized output is included. Peer evaluations were selected as the best measure of innovation. Innovation and productivity were identified as two separate dimensions of scientific/engineering output.

PART 3

THE PROBLEM AND ASSOCIATED HYPOTHESES

3.1 The Current Problem

The general question under study is what impact do organizational variables have upon scientific and engineering productivity and innovation.

The specific question under investigation in this work is which organizational variables from Table VI are associated with the innovation (original and useful output) and productivity (quantity of output) of scientists and engineers in R&D Laboratories?

As an aid to answering the problem, a number of hypotheses were formulated.

3.2 Hypotheses

Table VII presents the hypotheses examined in this study. There were 41 predictor and two criterion variables. Rather than present the hypothesis 82 times, the general form of the null hypothesis was H_0: The predictor variable is not linearly related to the criterion. The alternate hypothesis was, H_A: The predictor variable is linearly related to the criterion. The signs next to the predictors refer to the expected direction and significance of correlation (i.e. + means positively significant, - means negatively significant, 0 means not significant). The first sign refers to the innovation criterion and the second sign refers to the productivity criterion.

TABLE VII

ORGANIZATIONAL VARIABLES AND HYPOTHESES

HYPOTHESES		
INNOVATION	PRODUCTIVITY	VARIABLE NUMBER AND TITLE
0	0	1. Age
+	+	2. Educational level
+	+	3. Group heterogeneity-technical discipline
+	+	4. Current grade
0	0	5. Scientist/engineer ratio
0	0	6. Length of scientific/engineering experience
-	-	7. Length of Federal Government Employment as a scientist/engineer
-	-	8. Length of group membership
0	0	9. Per cent of time in nontechnical activities
+	+	10. Frequency of attendance at professional society meetings
+	+	11. Frequency of communication with other scientists/engineers within group on technical matters
+	+	12. Frequency of communication with other scientists/engineers outside group on technical matters
+	+	13. Frequency of communication with group leader on technical matters
+	-	14. Innovation pressure
-	+	15. Quantity pressure
+	+	16. Time pressure
-	0	17. Air Force relevancy pressure

TABLE VII - continued

HYPOTHESES		
INNO-VATION	PRODUC-TIVITY	VARIABLE NUMBER AND TITLE
+	+	18. Group leader professional competence
+	+	19. Extent participation - goal setting
+	+	20. Extent participation - decision making
0	0	21. Extent of group leader's empathy
+	-	22. Rewards for innovation
-	+	23. Rewards for quantity of output
+	+	24. Extent to which group leader evaluates work
-	+	25. Mission stability
0	0	26. Freedom/autonomy from group leader
0	0	27. Type of work(research, development, support)/group
0	0	28. Group leader age
+	+	29. Group leader educational level
+	+	30. Group-group leader homogeneity-technical discipline
-	+	31. Time in group leader position
+	+	32. Turnover
-	-	33. Group age
+	+	34. Budget trend: dollars/group
+	+	35. Budget trend: personnel/group
+	+	36. Number of projects (Work units)[1]/ group
+	+	37. Group size (number of scientists/ engineers)

[1] A Work unit was the smallest piece or "chunk" of identifiable work in a group.

TABLE VII - continued

HYPOTHESES		
INNO-VATION	PRODUC-TIVITY	VARIABLE NUMBER AND TITLE
+	+	38. Laboratory size (number of scientists/ engineers)
0	0	39. Laboratory
0	0	40. Division
0	0	41. Branch

The rationale behind the postulated direction and significance of the correlations was varied. In the ensuing discussion, the numbers refer to the variable number in Table VII.

One idea that accounted for more of the positive hypotheses than any other was the concept of stimulation from others. Whether it was stimulation due to number of contacts (variables 10,11,12,13,19 and 20), number of people (variables 37 and 38), skill of others (variables 2,4,18 and 29), new others (variables 8,32,35 and variable 31 relative to innovation), or diversity (variable 3), it was postulated that the stimulation has a positive linear relationship with performance. As Connor (1974) remarked:

> "Creative ability may be a social phenomenon. For example, perhaps the manifestly competent scientist receives his creative inputs totally

> from his colleagues, instead of generating them himself." (p.4)

Similarly, work in a number of areas (variable 36) or potentially new areas (variable 34 and variable 25 relative to innovation) were also postulated to provide stimulation and have positive linear relationships with performance.

Conversely, stagnation (variables 7 and 33) was postulated to have a negative linear relationship with performance.

Another group of variables was postulated to have no significant linear relationship with performance and was included mostly for statistical control purposes (variables 1,5,6,9,27,28,39,40 and 41).

Variable 14 was postulated to be linearly positively associated with innovation and negatively associated with productivity since the pressure for innovation was thought to stimulate original and useful output and hinder other output. Conversely, variable 15 was postulated to be linearly negatively associated with innovation and positively associated with productivity because the pressure for quantity was thought to stimulate quantity at the expense of quality (innovation). Variable 16 was postulated to be linearly positively associated with performance because time pressure was thought to be a stimulus to produce and at least some of the output should be innovative. Variable 17 was postulated

to have a negative linear association with innovation and a non-significant linear association with productivity because the relevancy pressure was postulated to put constraints on the work and at best provide no stimulus for quantity.

Similarly, the extent of group leader evaluation of work (variable 24) and his ability to evaluate due to common technical discipline (variable 30) was postulated to instill pressure for performance and thus have positive linear relationships with performance.

Stability of mission (variable 25) was postulated to be positively linearly related to productivity because it implies a group in an area long enough to know how to solve the routine problems that arise.

Time in group leader position (variable 31) was hypothesized to be positively linearly related to productivity because it implies a group leader familiar with most of the routine problems and solutions.

Rewards for innovation (variable 22) was hypothesized to be linearly positively related to innovation and negatively related to productivity, and rewards for quantity of output (variable 23) was postulated to be linearly negatively related to innovation and positively related to productivity because it was thought that behavior that is rewarded is reinforced.

Empathy (variable 21) was postulated to have a

non-significant linear relationship with performance because no reason for a significant relationship was seen.

Freedom (variable 26) was hypothesized to have a non-significant linear relationship with performance because although an argument could be presented for the condition helping some and hindering others, the net effect was believed to be zero.

PART 4

METHODOLOGY

The methodology included the use of questionnaires that were designed specifically for this research.[1]

4.1 Measurement

4.1.1 Choice of Questionnaire Technique

Data on organizational variables numbered 36 through 41 (Table VI) were obtained from extant laboratory records. Since the balance of the data required for this research (information concerning organizational variables numbered one through 35 in Table VI and the peer evaluations of performance) was not in existence, it was generated specifically for this study by the use of questionnaires.

Two separate questionnaires were employed. One questionnaire was sent to the group leaders (Appendix B) concerning the measurement of eight of the organizational variables (variables numbered 28 through 35 in Table VI). The other questionnaire was sent to the individual scientist/engineer within the groups (Appendix C). It contained measures for most of the organizational variables (variables numbered one through 27 in Table VI), as well as the measures of innovation and productivity.

[1] As noted in section 2.2.3, the terms group and group leader are used to refer to the lowest level formal organizational unit or work group, and the formal leader or immediate supervisor of the group, respectively.

4.1.2 Innovation and Productivity Measurement

Based partly on the technical expertise and familiarity with the work of peers, the criterion section of the last chapter established the logic and validity of using peer evaluations of innovation.

During a visit to the laboratories in April, particular attention was devoted to the issue of familiarity of peers with the work of others within his own group. In four of the five laboratories visited, there was little doubt concerning the familiarity within a group. However, there was doubt within the fifth laboratory. That laboratory was different from the others in that it employed a more multidisciplinary approach in its work teams and operated more toward the research end of the R&D spectrum. The image conveyed to this writer by the laboratory director was that of individuals working mostly alone, interacting mostly with their immediate supervisor, and interacting little with peers. Thus, the question of familiarity with other's work arose. Therefore, the laboratory in question was deleted from the sample.

Two other alternative rating schemes were under consideration before the on site visit: (a) the individuals within a group were to rate the innovation of other groups; and (b) the group leader was to rate the innovation of other groups. Both alternatives were discarded after it was learned that the familiarity of people of one group with the work in other

groups was very questionable.

Thus, it was decided that the individual scientist/engineer within a group could rate the innovation of the other scientists/engineers within his own work group. Individuals were asked to rate up to five other scientists/engineers within their own groups. Since at least two ratings were sought per individual, the average rating an individual received was used as the score for the individual. Also, use of at least two peer ratings permitted computation of interjudge agreement on the ratings.

The list of items included under output in a previous section includes (a) new or improved products, (b) new or improved processes, (c) new or improved techniques; (d) patents; (e) patent applications; (f) published papers in technical or professional journals (or Air Force technical reports/memorandums); (g) books; (h) manuscripts; (i) oral presentations to technical or professional audiences; and (j) requests for proposals. Unfortunately, organization records did not contain all this information. Self reports by individuals would not give a complete score for a group if all individuals did not reply. Thus, peer ratings of productivity were also included.

Innovation was defined as output that is original and useful, and productivity was defined as quantity of output in section 2.3.8. The questionnaire that was administered (Appendix C) contained the definitions of innovation and

productivity on page 1 and nine point rating scales for innovation and productivity on page 2.

4.1.3 Organizational Variable Measurement

As already mentioned, two questionnaires were employed.

The group leader questionnaire (Appendix B) was sent to the group leader of each of the groups in the survey. It contained eight straightforward questions to obtain data on the group leader and his group. Organizational variables numbered 28 through 35 from Table VI were the subject of the group leader questionnaire.

The individual questionnaire (Appendix C) was sent to the individual working level scientist/engineer. In addition to the peer ratings, this questionnaire contained questions dealing with organizational variables numbered one through 27 of Table VI in section 2.2.3. Some of the questions are demographic (like education), some are objective (like number of professional society meetings attended per year), and some are perceptual (like perceived participation).

Information on six of the organizational variables (numbered 36 through 41 in Table VI) was sought from laboratory records.

Thus, data from laboratory records, individual questionnaires and group leader questionnaires were all used as measures of organizational variables.

4.1.4 Construction of Questionnaires

The questionnaires employed herein were constructed in the following fashion.

After the list of variables had been identified (section 2.2.3), a first draft of the questionnaire was prepared.

The first draft of the individual questionnaire was pretested for readability and comprehensibility by administering it to 15 scientists and engineers in a local Army R&D Laboratory and to four Air Force Officers at RPI. The pretest questionnaire is in Appendix A.

The group leader questionnaire was not pretested since it only contains a few straightforward questions. It is in Appendix B.

The availability of information from the Air Force Laboratories' records was verified in a trip to the laboratories in early April.

Comments from the pretest and insights gained from the April laboratory trip were incorporated into the revised questionnaire (Appendix C).

The revised form was sent to Headquarters USAF for approval and assignment of a USAF Survey Control Number. This was a requirement under Air Force Regulation 178-8 (1973) as a means to control for duplication of surveys.

4.2 Subjects

The sample consisted of scientists and engineers in some Air Force R&D Laboratories.

4.2.1 Sample Selection[2]

In late February 1975, a trip to the laboratory headquarters (Air Force Systems Command) was undertaken to tentatively select a sample. With the help of Col. Robert Sigethy of the Plans Division in the headquarters staff, five laboratories out of a total of 13 in-house Air Force R&D Laboratories/Development Centers were chosen as candidates.

In selecting the five laboratories several criteria were employed.

One consideration was sample size. The five laboratories had approximately 250 groups and 1,800 scientists and engineers. Thus, there was an adequate number of potential work groups.

Another criterion was diversity of technical disciplines. Due to the diverse nature of their missions, the five laboratories employed engineers and scientists of various disciplines.

Another criterion was type of work. It was desired to cover the research spectrum of basic research, applied research, and development. The bulk of the laboratories' work

[2] This section borrows heavily from Air Force Systems Command (1974), laboratory records, and a meeting with Col. Sigethy on 26 Feb 75.

was in applied research and development, however, some work was toward the research end of the spectrum.

Another criterion was relative stability within the laboratories. Three of the 13 laboratories had radical reorganizations pending that had already been announced. Those laboratories were selected out.

Another criterion was distance. The remaining five laboratories were located in Florida, Texas, New Mexico, Colorado and California. The distance and associated logistical and financial considerations caused them to be deleted. Also, one of these five laboratories was eliminated for security considerations, and one for the geographic dispersion of its divisions.

The five candidate laboratories were all located at a midwestern Air Force Base. The bulk of the work in all five laboratories was in the applied research and development categories. The Air Force Laboratories engaged primarily in basic research were involved in the reorganization referred to above.

As noted previously, one of these five laboratories was deleted from the sample due to the question of the familiarity of people within a group with the work of others in the group. In May, another one of the candidate laboratories was deleted from the sample. The laboratory in question dropped out of this study because it was felt that it had recently been involved in too many surveys.

Prior to 1 July 1975, there were three organizational

levels below the laboratory level in each of the three laboratories: division; branch; and group. Effective at the time, the three laboratories, in conjunction with a fourth, were merged into one very large laboratory by the addition of a layer of management above the laboratory level. Until approximately 1 July 1976, the groups, branches and divisions were scheduled to remain intact as constituted before the merger.

Seven divisions constituted Laboratory A. One division was removed from the sample because of its total support function. The remaining six divisions contained about 75 groups and 550 scientists and engineers. About 20 groups were deleted because they either had only two[3] scientists/engineers or because the groups had recently been formed by internal reorganizations. Thus, 55 groups and 359 scientists/engineers from this lab were in the survey.

There were five divisions within Laboratory B. One division was eliminated because of its total support function. Two other divisions were deleted because its groups did little in-house work and were almost totally involved in contractual efforts. The remaining two divisions in the survey contained 26 groups and 215 scientists and engineers.

Laboratory C contained five divisions. One division was eliminated because of its total support function for the other four divisions. The remaining four divisions contained

[3] Groups with at least three professionals were needed to acquire at least two peer ratings per individual.

25 groups, one of which had only two scientists/engineers. Thus, 24 groups with 151 professionals from this laboratory were in the survey.

Overall, 105 groups and 725 scientists/engineers from three laboratories were surveyed.

4.2.2 Mailings and Personal Contact

On 2 June 1975, 105 group leader questionnaires and 620 individual questionnaires were distributed to the 105 groups.

As of 23 June 1975, only a 19% response rate had been achieved. On that date, 585 follow-up letters (Appendix D) were distributed.

As of 14 July 1975, (six weeks after the original mailing) the response rate was 27%.

Starting on 14 July (and lasting for 5 days), personal telephone contact was made with most of the non-respondents. Not all of the non-respondents were contacted because it was obvious from some of the conversations that some groups as a whole had decided not to answer the questionnaire due to the sensitive nature of the peer rating. Also, a number of people were on vacation or away on business during that time.

As of 11 August 1975 which was the cutoff date for receipt of questionnaires, 45.5% or 330 of the questionnaires had been returned. Apparently, the personal telephoning had been effective. However, it underscored the importance of personal contact when using something as sensitive and threatening as a peer rating. Hindsight could not emphasize this

too strongly.

4.2.3 Sample Description

The most efficient way to define the sample is by response rates per laboratory.

4.2.3.1 Response rates. Of the 330 questionnaires returned, 269 were individual contributors' questionnaires and 61 were from group leaders. A number of these were not usable. Some were blank, and some missed some data. A number came from various groups in which so few of the individual's peers had responded that the minimum requirement of at least two peer ratings had not been met. Without the peer ratings on an indivudual, his answers to the organizational variable questions were useless.

Given the previous reasons for loss of data, 154 of the obtained individual questionnaires were usable. These individuals were in 36 work groups. By usable is meant that the individuals had answered all the questions and at least two of their peers had rated them on innovation and productivity. The following response rates resulted from the 154 individual questionnaires in the three laboratories (Table VIII).

The response rates per laboratory were not the same. In Laboratories A and B there were two separate administrative problems that resulted in widespread misunderstandings that the questionnaires were in fact not approved for administration. Due to the misunderstandings, many individuals elected not to respond. In Laboratory C, there was no such misunderstanding.

TABLE VIII

INDIVIDUAL RESPONSE RATES

LABORATORY	NUMBER(1)	PERCENT(2)
A	64	21%
B	42	22%
C	48	38%
TOTALS	154	25%

(1) Number refers to number of usable individual questionnaires.

(2) Percent refers to the number as a percent of the individual questionnaires in the laboratory that had been sent out.

Two or more peer ratings per individual were also obtained on 35 others who did not respond. These additional data were used in the calculation of criterion reliability. Some of it was used in the productivity validation.

4.2.3.2 Deletion of group leader variables. It may be recalled that information for eight of the organizational variables was on the group leader questionnaire (Appendix B). Responses were not received from leaders of five of the groups from which usable information had already been received. Rather than contend with missing data on eight organizational variables for five groups, or delete five groups from the sample, it was decided to delete the eight group leader organizational variables. These were: group leader age; group leader educational

level; group-group leader homogeneity-technical discipline; time in group leader position; turnover; group age; budget trend-dollars/group; and budget trend-personnel/group.

4.2.3.3 Deletion of three other variables. Three other organizational variables were deleted.

The lab size variable was deleted because there were only three labs in the sample and little confidence could be ascribed to a finding based on three observations.

The division and branch variables were also deleted. The 36 groups were in 12 divisions and 22 branches. Since it was felt that blocking on division and branch yielded too many blocks, the two variables were deleted.

4.2.3.4 Sample characteristics. The average educational level for the 154 individuals was between a B.S. and a M.S. degree. It was somewhat of a surprise to discover that in an R&D environment almost one half of the sample (72 of 154) had only a bachelors degree. Sixty-one had a M.S. degree and 21 possessed a Ph.D. Seventy nine per cent of the sample were engineers and the remaining 21% were mostly physical scientists.

Twenty per cent of the sample were military officers. They were in the grades of Lieutenant and Captain. Eighty per cent of the sample were Civil Servants. Most of the civilians were in the GS 12 and 13 grades.

The average age was 35.7 years. Length of scientific/engineering experience averaged to 11.3 years and the mean length of Federal Government Employment as a scientist or engineer was 9.3 years. All three variables were highly correlated.

The average amount of time spent on non-technical activities was 28%. This number was partly a reflection of the contract monitoring activities performed by the scientists/engineers in the labs.

A more complete description of the sample is offered via Appendix E. It contains the means, standard deviations and correlation matrix for the 154 respondees. The coding scheme contained in Appendix G explains the values of the variables.

4.3 Analytic Methods

A listing of all the computer programs utilized in conjunction with the following analytic methods is in Appendix H.

4.3.1 Individual and Group Level Analyses

Section 2.1 of this dissertation concluded with the message that an individual's perception of organizational phenomena should not be treated as a measure of the organization, but as a measure of the individual. However, it is possible that significant relationships exist between the innovation and productivity of the individuals, and individual measures. Thus, an individual level of analysis was performed that consisted of calculating the relationships between the individual demographic and perceptual variables, and individual performance. This left unanswered the question of how the individual perceptions relate to organizational variables.

The measure that was devised as a measure of the organizational variable is the mean value for the group on that variable. Thus, a group level of analysis was also performed. It consisted of checking the relationship of the mean innovation and productivity scores for the group with the mean value on the organizational variable for the group.

The 154 individuals did not constitute all the scientists/engineers working in the 36 groups. Fourteen of the groups had a 100% response rate. The other 22 groups had response rates ranging from 60% to 89% because 35 people in the 22 groups did not respond. However, peer ratings were obtained on the 35 individuals who did not respond. Group criteria scores were formed based on the 154 individuals' criteria scores as well as based on 189. A test of difference between the two sets of scores revealed no significant differences. Thus, no significant distortion in the group scores was introduced by using group scores based on less than all the individuals in the groups.

For the remainder of this chapter and the next chapter, the semantic differentiation was dropped between individual demographic and perceptual variables versus group averages for the organizational variables. This distinction is reintroduced in the last chapter. In the interim, the term predictor variable is used.[4] The reader can easily discern which level

[4] The term criterion variable refers to innovation or productivity at the individual or group level.

of analysis (individual or group) is under discussion by noting the sample size. A sample size of 154 consists of the individual level of analysis. Thirty-five[5] is the sample size for the group level analysis.

A description of the groups is contained in Appendix F. The means, standard deviations, and correlation matrix for the 35 groups are listed there.

4.3.2 Validity and Reliability

4.3.2.1 Criterion variables. Reliability of the criteria variables was a rather straightforward calculation. Since it had been decided to use the average rating of all the innovation ratings an individual received as his innovation score (and likewise for productivity), reliability means the reliability of the mean of k judges (i.e. the degree of inter-judge agreement). As Ebel (1951) remarked: "If decisions are based upon average ratings, it of course follows that the reliability with which one should be concerned is the reliability of those averages".(p.408) The Spearman-Brown prediction formula, as discussed in section 4.5 of Winer (1971), was used to calculate the reliability of the mean of k judges. Recalling that individuals were rated by two, three, four or five judges, eight separate reliability calculations were required (four for innovation and four for productivity).

[5] The group level analysis was started with 36 groups. However, one of the groups was subsequently identified as an outlier (section 5.2.2.2) and deleted from the analysis.

It was obvious from an examination of the raw ratings that there were a few raters who strongly disagreed with two or three other raters who were in close agreement when rating the same individual. Of the 1,110 ratings performed (555 for innovation and 555 for productivity), 19 ratings differed from the average of two or three other raters, who were in close agreement, by at least four points and up to six and one half points on the rating scales. These 19 ratings were deleted along with the associated 19 ratings from the innovation, productivity pair of ratings given by the rater who was in strong disagreement.

Validity of the criteria was not as straightforward as reliability. Since the definition of innovation required a subjective evaluation, and since objective measures of R&D output all had drawbacks as discussed in the criterion section (2.3), there was no good objective measure that could have been used for a validity check especially in military R&D Labs. Validity rests in the face validity of the definition of innovation, and in the professional expertise and familiarity with the work of the scientists and engineers who performed the rating. One could also argue validity since the average rating, or consensus of several other professionals, was used as the criterion score.

Face validity was examined by scrutinizing the distributions of the innovation and productivity scores. It seems

reasonable that human behavior like innovation or productivity should be normally distributed. If the distributions had been weird multimodal curves, or drastically skewed to one end of the scale, it would have implied that the raters either did not understand the definitions of innovation and productivity or some other serious errors were operating.

The distributions were examined by checking the plots of the mean innovation and productivity scores versus the frequency of the scores. A more rigorous examination was performed by checking the bivariate distribution of innovation and productivity. Using a technique recently developed by Paulson and Thornton(1975) the assumption of a bivariate normal distribution was tested. If that assumption was not rejected, the assumptions of normal marginal distributions of innovation and productivity could also not be rejected. Normally shaped curves implied that the use of the scales made sense to the raters, i.e. the scales possessed face validity.

A validity test on the productivity ratings from one lab was performed. The number of in-house Air Force Technical Reports (TRs) and Air Force Technical Memorandums (TMs) was a measure of productivity. In-house reports were distinguished from contractor reports because in-house reports were a direct reflection of in-house effort, whereas contractor reports were primarily a reflection of contractor effort.[6] Laboratory A

[6] Personal communication with the Plans Officer from Laboratory A on 16 July 1975.

paid attention to the number of TRs and TMs and maintained records on same. A validation of the productivity ratings for the individuals in Laboratory A was performed by correlating them with the number of TRs and TMs.

4.3.2.2 Predictor variables. In order to make a decision concerning use of the mean perception of the group as the measure of the respective organizational variable, the variance of the perceptual variables within each of the groups was examined. The perceptual variables are the 13 variables within the questionnaire (Appendix C) concerning the individual's perceptions (mostly toward his group leader) via nine point rating scales. The perceptual variables are: quantity, innovation, time and Air Force relevancy pressures; group leader professional competence; participation on goal setting and routine decision making; group leader's empathy; rewards for quantity of and innovative output; group leader's evaluation of work; mission stability, and freedom/autonomy. The magnitude of the variance, especially relative to the mean, provided a rough measure of the stability of the mean perception of the group. This was needed in order to make the decision concerning use of the mean.

The correlations of the various demographic variables with the perceptual variables were also examined. The demographic variables are: age; educational level; grade; time in group; scientist or engineer; length of scientific/engineering experience; length of Federal Government Employment as a

scientist/engineer; military or civilian; age in four categories[7], and the age four interaction with educational level[7]. The correlations were examined to help decide whether to use the raw individual's perceptions or to rescale the perceptions by covarying out the demographic influences.

One way to check the reliability of the predictor variables was via a cross validation. Comparison of the multiple correlation coefficient with the cross validation coefficient provided a measure of the consistency or reliability with which the questionnaires were completed. Reliability is implied if no significant differences between the two coefficients are observed.

4.3.3 Hypotheses Testing Techniques

4.3.3.1 Correlation analysis. As previously indicated, the general form of the null hypothesis was that the predictor variable was not linearly related to the criterion variable. Thus, examination of the zero order correlations between predictor variables and criterion variables for statistical significance was performed to test the hypotheses.

4.3.3.2 Multiple regression analysis. Recognizing that several of the predictor variables were correlated with each other, it was decided to look at the partial correlations via Ordinary Least Squares Regression. The results of Ordinary

[7] The coding of these two variables is explained in Appendix G.

Least Squares Regression were compared with the results from a Robust Regression[8] for the group level productivity data (section 5.2.2.2) due to the presence of an outlier.

4.3.3.3 Canonical correlation analysis. Since the two criterion variables were correlated, the need to perform a multivariate analysis in addition to the two separate univariate analyses arose. Canonical correlation analysis is a multivariate technique well suited to the problem of exploring the relationships between two sets of variables.

Significance testing in canonical correlation analysis requires pq degrees of freedom, where p is the number of predictor variables and q is the number of criterion variables (Tatsuoka, 1971, p.188). For the group level of analysis, there were 35 observations. Therefore, at most 17 predictor variables could have been used with the two criterion variables to satisfy a minimum requirement of at least one observation per degree of freedom. It was decided to include those variables in the group level canonical correlation analysis that were significant in either the zero order correlation analysis, or regression analysis, for both innovation and productivity.

One minor issue with the use of canonical loadings is that one must decide what magnitude is required to be

[8] The Robust Regression used is currently under development by A. Paulson and A. Schumaker of RPI as a part of Schumaker's dissertation.

classed as a substantial loading since there are no significance tests for each loading. It was decided that loadings greater than or equal to 0.3 in absolute value were substantial in this study. That level of loading included the larger loadings and verified several variables that were significant in the correlation and regression analyses.

4.3.3.4 Linear models. The linear model for the individual level analysis contained 30 main effect terms and seven two-way interaction terms. The model was of the general form

$$Y = b_0 + b_i X_i \quad \text{where } i = 1,\ldots,37.$$

The 37 terms are listed in Table XII of section 5.2.1. The coding scheme is in Appendix G.

The linear model for the group level analysis contained 34 main effect terms, one second order term, and one two-way interaction term. The model was of the general form

$$Y = b_0 + b_i X_i \quad \text{where } i = 1,\ldots,36.$$

The 36 terms are listed in Table XXII of section 5.2.2. The coding scheme is in Appendix G.

PART 5

RESULTS

5.1 Validity and Reliability

The validity and reliability of the variables were assessed before proceeding with hypotheses testing.

5.1.1 Criterion Variables

5.1.1.1 Reliability. The research design required that an individual must be rated by at least two peers before the ratings were used in this study. This requirement was effected, partly, so that the reliability of the ratings could be examined. Some individuals were rated by two of their peers, some by three, some by four, and some by five. Thus, four separate reliability calculations were performed for innovation, and four for productivity. Arithmetic averages of the four reliability coefficients for innovation and of those for productivity are also presented. The results of the reliability calculations and the number of ratings upon which each calculation was based are presented in Table IX.

Several findings are apparent from the data shown in Table IX. Firstly, substantial agreement between the raters in completing the ratings on their peers is indicated by the magnitude of the reliability coefficients. Secondly, the reliability of the productivity scale is slightly higher than the reliability of the innovation scale. This is somewhat as

TABLE IX

CRITERIA RELIABILITY

NUMBER OF RATERS	NUMBER OF RATINGS	$r^{(1)}$	
		INNO-VATION	PRODUC-TIVITY
2	156	.52	.66
3	216	.63	.65
4	124	.77	.78
5	40	.73	.80
AVERAGE $r^{(1)}$		.66	.72

(1) r is the Spearman-Brown reliability coefficient.

expected since productivity might have been an easier construct to grasp than innovation. Thirdly, the magnitude of the reliability increases with increased number of raters.

Using the definition of innovation that was used in this research, Steger (1975) also found substantial agreement among the raters. He commented:

> "In the course of our work the nomination of people to the three subgroups (either innovative, productive or nonproductive), posed little if any problem for those asked to do the nominating. In fact, the degree of consensus among those nominating individuals for the subgroups was truely surprising." (p.2)

5.1.1.2 Face validity. Plots of the mean innovation and productivity scores versus the frequency of the scores revealed two approximately normally shaped distributions. A more rigorous examination was performed by checking the bivariate distribution of innovation and productivity. Using a technique recently developed by Paulson and Thornton (1975), and a computer program recently written by A. Schumaker of Rensselaer implementing the technique, the null hypothesis of a bivariate normal distribution was not rejected when tested. Therefore, the null hypotheses of normal marginal distributions of innovation and productivity were also not rejected. Normally shaped curves implied face validity to the raters and the absence of serious errors in the completion of the ratings.

Further assurance that the criteria definitions and scales were understood and used by the raters was obtained by examining the relationship of the productivity scores to the innovation scores. Productivity was defined as quantity of output and innovation was defined as a particular kind or subset of output, i.e. output that is original and useful (section 2.3.8). It appears that these definitions were understood and used by the raters since the productivity scores are significantly greater than ($p = .0015$) the innovation scores. This was generally the expectation since innovation is thought to be a more rare event than productivity.

5.1.1.3 Productivity validation. A validation of the productivity ratings via comparison with number of in-house Air Force Technical Reports (TRs) and Air Force Technical Memorandums (TMs) was attempted herein. Productivity ratings were obtained on 78 individuals in the laboratory that maintained records on TRs and TMs.

A plot of the number of TRs and TMs revealed a gross departure from any assumption of normalcy. Thus, Spearman correlation coefficients were calculated, versus Pearson correlation coefficients.

After examining the plot, it was decided to also check the correlation of the productivity ratings with number of TRs and TMs squared, since it was thought that a second order effect was present. The results of the calculations are contained in Table X.

TABLE X

PRODUCTIVITY VALIDATION (N = 78)

	$r^{(1)}$	$p^{(2)}$
	PRODUCTIVITY	
Number of TRs and TMs	.19	.04
(Number of TRs and TMs)^2	.21	.03

(1) r = Spearman correlation coefficient.

(2) p = probability of relationship occurring by chance.

Both relationships, although statistically significant, are not very strong. However, they compare with similar validation efforts that have been attempted by other researchers.

Taylor, et al. (1961), reported a correlation of .08 between a productivity ranking performed by peers, and number of technical reports and memoranda (p.38). Ellison, et al. (1968), reported a correlation of .08 between a productivity ranking performed by immediate supervisors and number of technical reports (p.38).

The validity coefficients obtained in this effort may be a reflection of the validity of the records kept in the laboratory from which the information was obtained. Also, the coefficients may reflect that the raters had more in mind when rating peers than number of TRs and TMs. It may be recalled that output also includes papers published in journals, patents, oral presentations, etc. These were not included in the present productivity validation.

5.1.2 Predictor Variables

5.1.2.1 Perceptual variables. These include the 13 variables in the questionnaire (Appendix C), concerning the individual's perceptions, mostly toward his group leader. The perceptual variables are: quantity, innovation, time, and Air Force relevancy pressures; group leader professional competence; participation on goal setting and routine decision making; group leader's empathy; rewards for quantity of,

and innovative output; group leader's evaluation of work; mission stability; and freedom/autonomy. To check the stability of the perceptual variables, the variance of each of the perceptual variables within each of the groups was examined. A certain stability of the mean perception within a group was evidenced by the absence of large variances. Thus, it was decided to use the mean perception of the group as the measure of the respective organizational variable in the group level analysis.

The relationships of the various demographic variables with the perceptual variables were also analyzed. The demographic variables consist of: age; educational level; grade; time in group; scientist or engineer; length of scientific/engineering experience; length of Federal Government Employment as a scientist or engineer; military or civilian; age in four categories;[1] and the age interaction with educational level.[1] If certain of the demographic items had high relationships with the perceptual variables, the perceptual items could have been rescaled by covarying out the demographic influences. However, none of the perceptual variables had high relationships with the demographic items as none of the associated correlations even reached statistical significance. Thus, it was decided to use the raw individual's perceptions for the individual level analysis.

[1] The coding of these two variables is explained in Appendix G.

Appendix E contains the correlations of the demographic and perceptual variables, as well as the correlations for all the predictor variables in upper right triangular matrix format.

5.1.2.2 Cross validation. By cross validating and comparing the relative magnitude of the multiple correlation coefficient (R) with the correlation of the predicted and actual scores for the subsample (r), a measure of reliability was achieved. One hundred and four individuals were randomly withdrawn from the original sample and a stepwise regression using the productivity scores was performed resulting in an R = .416. The associated prediction equation was used to generate predicted productivity scores for the remaining subsample of 50. The actual productivity scores and the predicted productivity scores for the 50 individuals have an r = .355. Whereas a null hypothesis of no difference between R and r was not rejected, it implied that the relationship is consistent, and thus the questionnaires were reliably completed.

5.2 Tests of Hypotheses

The notation used throughout this section is explained in Table XI.

The format for the remainder of this chapter consists of presenting the individual level results of the hypotheses tests for innovation, followed by the results of

TABLE XI

NOTATION FOR HYPOTHESES TESTS

SYMBOL	MEANING
r	Sample Correlation Coefficient.
N	Number of observations (individuals or groups) upon which the calculation was based. (1)
p	Probability of the relationship occuring by chance.

(1) The reader may recall that an N of 154 implies the individual level analyses, and an N of 35 implies the group level analyses.

the regression analysis for innovation, then likewise for productivity, followed by the canonical analysis and a summary of the tests. A similar format is followed for the group level results.

5.2.1 Individual Level Analyses

The variable abbreviations used in the individual level analyses are defined in Table XII.

TABLE XII

VARIABLE ABBREVIATIONS (N = 154)

ABBREVIATION	VARIABLE
AGE	Age
EDCTN	Educational level
IGHOMO	Individual-group homogeneity (technical discipline)

TABLE XII - continued

ABBREVIATION	VARIABLE
GRADE	Grade
TINGRP	Length of group membership
SCIORE	Scientist or Engineer
TSEEXP	Length of Scientific/Engineering experience
TFEDSE	Length of Federal Government Employment as a scientist or engineer
NWORKA	Number of Work Areas
TNOTCH	Per cent of time in nontechnical activities
PROMTG	Frequency of attendance at professional society meetings
COMWIG	Frequency of communication with other professionals within own group on technical matters
COMOUT	Frequency of communication with other professionals outside own group but within laboratory on technical matters
COMWGL	Frequency of communication with group leader on technical matters
QPRESS	Quantity pressure
IPRESS	Innovation pressure
TPRESS	Time pressure
RELPRS	Air Force relevancy pressure
GLPCMP	Group leader professional competence
PARTG	Participation on goal setting
PARTDM	Participation on routine decision making

TABLE XII - continued

ABBREVIATION	VARIABLE
EMPTHY	Group leader's empathy
RWDSQ	Rewards for quantity of output
RWDSI	Rewards for innovation
EVAL	Group leader's evaluation of work
MISSTB	Mission stability
FREEDA	Freedom/autonomy
TWORK	Type of Work
MILCIV	Military or civilian
AGE4	Age in four categories
AG4XED	AGE4 interaction with EDCTN
EMXCOL	EMPTHY interaction with COMWGL
EMXLCP	EMPTHY interaction with GLPCMP
EMXPG	EMPTHY interaction with PARTG
EMXRWQ	EMPTHY interaction with RWDSQ
EMXRWI	EMPTHY interaction with RWDSI
EMXEVL	EMPTHY interaction with EVAL

5.2.1.1 Innovation. Hypotheses were tested using 26 variables (variables numbered 1,2 and 4 through 27 in Table VII) relative to innovation at the individual level. The hypotheses and calculated correlations for the 26 variables relative to innovation are contained in Table XIII.

TABLE XIII

TESTS OF HYPOTHESES FOR INNOVATION (N = 154)

VARIABLE(1)	H_0(2)	r(3)	p(4)
AGE	0	-.232	<.01
EDCTN	+	-.304	<.01
GRADE	+	.038	N.S.
SCIORE	0	.027	N.S.
TSEEXP	0	-.183	<.05
TFEDSE	-	-.212	<.01
TINGRP	-	-.146	N.S.
TNOTCH	0	-.134	N.S.
PROMTG	+	.084	N.S.
COMWIG	+	.161	<.05
COMOUT	+	.028	N.S.
COMWGL	+	-.050	N.S.
IPRESS	+	-.031	N.S.
QPRESS	-	-.146	N.S.
TPRESS	+	-.030	N.S.
RELPRS	-	.148	N.S.
GLPCMP	+	-.041	N.S.

(1) The abbreviations used are defined in Table XII.

(2) + means positively significant, - means negatively significant, 0 means not significant.

(3) For r = .158, p = .05 and for r = .207, p = .01.

(4) N.S. means not significant.

TABLE XIII - continued

VARIABLE(1)	H_0(2)	r(3)	p(4)
PARTG	+	.028	N.S.
PARTDM	+	-.063	N.S.
EMPTHY	0	.106	N.S.
RWDSI	+	.086	N.S.
RWDSQ	-	-.042	N.S.
EVAL	+	-.036	N.S.
FREEDA	0	.100	N.S.
MISSTB	-	-.056	N.S.
TWORK	0	.018	N.S.

Age (AGE) was found to be negatively related to innovation (r = -.232). Thus, the null hypothesis that age and innovation are not linearly related is rejected. Further comment is reserved until an interaction term involving age is added.

Educational level (EDCTN) is negatively associated with innovation (r = -.304). However, it may be recalled that educational level was reverse coded such that Ph.D. was coded one, M.S. two, and B.S. was coded three. Thus, the observed relationship between education and innovation implies that high education is associated with high innovation, and vice versa. Therefore, the hypothesis of a positive linear

relationship between education and innovation (which was formulated before it was decided to reverse code education) was supported.

The length of scientific/engineering experience (TSEEXP) was found to be negatively related to innovation (r = -.183). The length of scientific/engineering experience has a high relationship with age (r = .924). This may account for the negative relationship of the length of scientific/ engineering experience with innovation.

The length of Federal Government Employment as a scientist or engineer (TFEDSE) is negatively associated with innovation (r = -.212). This confirmed the expectation that length of employment and innovation would be negatively related. The relationship was originally hypothesized to be linearly negative because it was thought that the length of Federal Government Employment as a scientist or engineer might have been a proxy measure of intellectual stagnation. That is, the longer a person worked for the Federal Government as a scientist or engineer, the more complacent and isolated from other work experiences, and obsolescent he became. It is difficult to determine if this model is so because this variable has a high association (r = .738) with age.

The frequency of communication with other professionals within the group on technical matters (COMWIG) is positively related to innovation (r = .161). This confirmed the hypothesis of a positive linear association between this

communication variable and innovation. Stimulation due to contact with other professionals had been anticipated. However, of all the communication variables, only communication within the group was found to be significantly related to innovation. This may be due to the much higher number of contacts within the group relative to the other three communication variables. The average number of contacts per week on technical matters within the group is close to 13. However, the corresponding number for contacts outside of the group is less than five and for contacts with the group leader is about three. The average number of professional society meetings per year is about .9. Thus, the pattern of results for communication may be partly due to the relative number of contacts if stimulation is proportional to contact.

Twelve variables concerning the group leader (from innovation pressure (IPRESS) through freedom/autonomy (FREEDA) in Table XIII) are all not linearly related to innovation ($p > .05$). This could cause one to wonder about the influence that the group leader has on the innovation of professionals in his group.

In addition to the 26 variables referenced in Table XIII, 11 additional variables were formulated during the data analysis phase. There were no hypotheses associated with these 11 variables. The 11 variables and calculated correlations with innovation are listed in Table XIV.

TABLE XIV

RESULTS OF 11 VARIABLES WITH INNOVATION (N = 154)

VARIABLES(1)	r(2)	p(3)
MILCIV	.034	N.S.
NWORKA	-.123	N.S.
IGHOMO	.128	N.S.
AGE4	-.253	<.01
AG4XED	-.365	<.01
EMXCOL	-.023	N.S.
EMXLCP	.039	N.S.
EMXPG	.067	N.S.
EMXRWQ	-.001	N.S.
EMXRWI	.075	N.S.
EMXEVL	.038	N.S.

(1) The abbreviations used are defined in Table XII.

(2) For r = .158, p = .05 and for r = .207, p = .01.

(3) N.S. means not significant.

Age[2] (in four categories - AGE4) has a negative relationship with innovation (r = -.253). Even more importantly, an age x education interaction variable[2] (AG4XED) has a higher negative relationship with innovation (r = -.365).

[2] The coding and explanation of these two variables are contained in Appendix G.

It should be recalled that education had been reverse coded such that Ph.D. was coded one, M.S. two and B.S. three. Thus, the image suggested by the negative linear relationship of the interaction term with innovation is that of older, less educated individuals scoring lower on innovation.

Having tested the hypotheses and examined all the zero order correlations, the regression analysis was performed. Table XV is a summary of the regression data.

TABLE XV

STEPWISE REGRESSION ANALYSIS FOR INNOVATION (N = 154)

STEP	VARIABLE(1)	MULTIPLE r	SIGN OF BETA COEFFICIENT	FINAL PARTIAL F(2)
1	AG4XED	.3652	-	34.63
2	GRADE	.4293	+	10.70
3	COMWIG	.4486	+	8.07
4	COMWGL	.4726	-	6.50
5	RWDSI	.4940	+	4.04

(1) Abbreviations used are in Table XII.

(2) $F_{1,148,.95} = 3.91$ and $F_{1,148,.99} = 6.82$

The age x education interaction variable (AG4XED) has a negative association with innovation, once the effects of the other predictors are partialed out. In fact, it accounts for more variance than do all the other predictors.

The interaction variable supports the image of the older, less educated individuals scoring lower on innovation.

Federal Civil Service/Military Grade Level has a positive relationship with innovation, given the presence of the other variables. This is of some interest because grade had been hypothesized to be positively related with innovation. The positive relationship may suggest that innovative individuals are being promoted.

Communication with other professionals within the group on technical matters (COMWIG) has a positive relationship with innovation (partial $F = 8.07$). This relationship is in accordance with the positive relationships between this communication variable and innovation evidenced by $r = .161$.

Communication with the group leader on technical matters (COMWGL) has a negative relationship with innovation, after the effects of the other predictors are partialed out. This was suprising because a positive linear relationship between this communication variable and innovation had been hypothesized. The idea of stimulation due to contact with others was previously mentioned. This concept seems to be supported by the positive association of communication <u>with-in</u> the group and innovation. Did the negative association of communication with the group leader and innovation imply inhibition due to contact with the leader? Were the group leaders telling their subordinates how not to do things, and

what had not worked before? The answers to these questions are unknown, as is the reason for the negative relationship.

The rewards for innovation variable (RWDSI) has a positive relationship with innovation (partial F = 4.04). Perhaps this finding with Skinnerian overtones implies an instance in which the group leader has some influence on the innovation of the professionals in his group.

Once the regression had been performed, the residuals were examined. Plots of the residuals versus the predictor variables in the equation, as well as versus the predicted values of innovation revealed no abnormalities in the residuals. A plot of the 154 residuals on normal probability paper did not cause the assumption of normally distributed residuals to be rejected. Thus, reasonable assurance was obtained that the assumptions required for significance tests in regression were not violated.

5.2.1.2 Productivity. The hypotheses and calculated correlations for 26 variables relative to productivity at the individual level are contained in Table XVI.

Age is negatively related to productivity (r = -.248). This lead to the rejection of the null hypothesis that no linear relationship between age and productivity existed. Further comment is reserved until an interaction term involving age is added.

TABLE XVI

TESTS OF HYPOTHESES FOR PRODUCTIVITY (N = 154)

VARIABLE(1)	H_0(2)	r(3)	p(4)
AGE	0	-.248	<.01
EDCTN	+	-.195	<.05
GRADE	+	.017	N.S.
SCIORE	0	.007	N.S.
TSEEXP	0	-.192	<.05
TFEDSE	-	-.196	<.05
TINGRP	-	-.060	N.S.
TNOTCH	0	-.038	N.S.
PROMTG	+	-.002	N.S.
COMWIG	+	.210	<.01
COMOUT	+	.043	N.S.
COMWGL	+	.056	N.S.
IPRESS	-	.059	N.S.
QPRESS	+	-.014	N.S.
TPRESS	+	.063	N.S.
RELPRS	0	.192	<.05
GLPCMP	+	.102	N.S.

(1) The abbreviations used are defined in Table XII.

(2) + means positively significant, - means negatively significant, 0 means not significant.

(3) For r = .158, p = .05 and for r =.207, p = .01.

(4) N.S. means not significant.

TABLE XVI - continued

VARIABLE(1)	H_0(2)	r(3)	p(4)
PARTG	+	.214	<.01
PARTDM	+	.108	N.S.
EMPTHY	0	.237	<.01
RWDSI	-	.199	<.05
RWDSQ	+	.011	N.S.
EVAL	+	.078	N.S.
FREEDA	0	.030	N.S.
MISSTB	+	.065	N.S.
TWORK	0	-.100	N.S.

Educational level (EDCTN) is negatively associated with productivity (r = -.195). It may be recalled that educational level was reverse coded. Thus, the hypothesis of a positive linear relationship between education and productivity was supported by the data.

Both the length of scientific/engineering experience (TSEEXP) and the length of Federal Government Employment as a scientist or engineer (TFEDSE) are negatively related to productivity(r = -.192 and -.196, respectively). Both of these predictor variables are highly associated with age (r = .924 and r = .738, respectively). Age is negatively related to productivity (r = -.248). This may account for

the negative relationships of the length of scientific/engineering experience and the length of Federal Government Employment as a scientist or engineer with productivity.

The frequency of communication with other professionals within the group on technical matters (COMWIG) is positively associated with productivity (r = .210). This confirmed the hypothesis of a positive linear relationship between this communication variable and productivity.

Four variables concerning the group leader are positively related to productivity. Air Force relevancy pressure (RELPRS) is positively related to productivity (r = .192). The rewards for innovation (RWDSI) variable has a positive relationship with productivity (r = .199). The reader may recall that the rewards for innovation variable is positively related to innovation as evidenced by the regression. Thus, rewards for innovation has a positive relationship with both innovation and productivity. Participation on goal setting (PARTG) and the group leader's empathy (EMPTHY) are both positively related ($p < .01$) with productivity. Further comment is reserved until some interaction terms involving empathy are discussed.

In addition to the 26 variables referenced in Table XVI, 11 additional variables were formulated during the data analysis phase. The 11 variables and calculated correlations with productivity are listed in Table XVII.

TABLE XVII

RESULTS OF 11 VARIABLES WITH PRODUCTIVITY (N = 154)

VARIABLE(1)	r(2)	p(3)
MILCIV	.032	N.S.
NWORKA	-.112	N.S.
IGHOMO	.121	N.S.
AGE4	-.217	<.01
AG4XED	-.263	<.01
EMXCOL	.098	N.S.
EMXLCP	.188	<.05
EMXPG	.264	<.01
EMXRWQ	.096	N.S.
EMXRWI	.203	<.05
EMXEVL	.173	<.05

(1) The abbreviations used are defined in Table XII.

(2) For r = .158, p = .05 and for r = .207, p = .01.

(3) N.S. means not significant.

Four of the six interaction terms involving empathy in Table XVII are positively related to productivity. This may be due primarily to the positive relationship of empathy and productivity. In ascending order of magnitude, the interactions of empathy with group leader evaluation of work (EMXEVL), empathy with group leader professional competence

(EMXLCP), empathy with rewards for innovation (EMXRWI), and empathy with participation on goal setting (EMXPG) all are positively related to productivity (r = .173, r = .188, r = .203, and r = .264, respectively). The variable formed by the interaction of empathy with participation on goal setting has the highest zero order correlation of all the predictor variables with productivity (r = .264).

Age (in four categories - AGE4) has a negative relationship with productivity (r = -.217). Even more importantly, the age x education interaction variable (AG4XED) has a higher negative relationship with productivity (r = -.263). The negative relationship of this interaction term with productivity implies that older, less educated individuals score lower on productivity. This is analogous with the implication formed by the innovation analysis.

Attention is now focused on the regression analysis since all the hypotheses have been tested and all the zero order correlations have been examined. Table XVIII is a summary of the regression analysis.

The variable formed by the interaction of empathy with participation on goal setting (EMXPG) has a positive relationship with productivity, once the effects of the other predictor variables are partialed out. The interpretation of this interaction term centers around the fact that both elements in the interaction dealt with the group leader. The group leader's empathy had been defined in the questionnaire

TABLE XVIII

STEPWISE REGRESSION ANALYSIS FOR PRODUCTIVITY (N = 154)

STEP	VARIABLE(1)	MULTIPLE r	SIGN OF BETA COEFFICIENT	FINAL PARTIAL F(2)
1	EMXPG	.2636	+	11.47
2	AG4XED	.3712		
3	COMWIG	.4074	+	4.08
4	GRADE	.4284	+	9.13
5	AGE	.4602	-	20.23
6	AG4XED	.4582	(REMOVED)	

(1) Abbreviations used are in Table XII.

(2) $F_{1,149,.95} = 3.91$ and $F_{1,149,.99} = 6.82$.

(Appendix C) as "he understands my feelings." Participation with the group leader on goal setting had been defined in the questionnaire as "he shares this function with me." The interaction of the two variables implies a quality dimension of participation, or genuine participation. A picture of the leader attempting to really understand the individuals as he shares the goal setting function with them came to mind. This could be contrasted to the "make them 'think' they are participating-but really retain all the power" type attitude.

Age was found to be negatively related to productivity by both the regression and correlation analyses. In fact, age is so highly related to productivity (partial F = 20.23) that it replaced the age x education interaction vari-

able (AG4XED) from the regression.

Grade is positively related to productivity once the effects of the other predictor variables are partialed out. This is of interest because grade had been hypothesized to have a positive linear relationship with productivity.

Communication with other professionals within the group on technical matters (COMWIG) was found to have a positive relationship with productivity. This communication variable is consistently related to performance. It is positively related to both criteria.

The residuals due to the regression were examined. This examination did not cause any of the assumptions required for significance tests in regression to be rejected.

Once the relationships of the predictors to innovation and productivity separately had been analyzed, the relationships of the predictors to innovation and productivity jointly were analyzed.

5.2.1.3 Canonical analysis. The relationship between innovation and productivity was found to be high ($r = .735$). This compares with a high relationship between immediate supervisor rankings of creativity and productivity ($r = .70$) found by Ellison, et al. (1968). Andrews and Farris (1972) found a high relationship between judge rankings of innovation and productiveness ($r = .70$). McCarrey and Edwards (1973) reported a strong relationship between

peer rankings of creativity and productivity (r = .75). Productivity and innovation do indeed seem to be highly related.

Since there are two criterion variables and 37 predictor variables, two canonical roots were formed with the following results.

TABLE XIX

CANONICAL ROOTS (N = 154)

ROOTS(1)	CHI SQUARE	d.f.(2)	p
.3992	68.28	38	.003
.2879	45.50	36	.139

(1) The roots = R^2, i.e. the amount of shared variance between the two canonical variate sets.

(2) D.f. means degrees of freedom.

Since the second canonical root is not significant, it is not discussed further.

The redundancy of the criterion set for the first root is .3177. In other words, almost one third of the variance of the criterion variables is shared by the predictor canonical variates.

Table XX contains the canonical loadings for the one significant canonical root.

TABLE XX

CANONICAL LOADINGS (N = 154)

VARIABLE(1)	LOADING
PRODUCTIVITY	.9985
INNOVATION	.7713
AGE	-.3981
EDCTN	-.3291
IGHOMO	.1960
GRADE	.0301
TINGRP	-.1089
SCIORE	.0143
TSEEXP	-.3092
TFEDSE	-.3187
NWORKA	-.1816
TNOTCH	-.0741
PROMTG	.0071
COMWIG	.3325
COMOUT	.0681
COMWGL	.0764
QPRESS	-.0397
IPRESS	.0839
TPRESS	.0901
RELPRS	.3041

(1) The abbreviations used are defined in Table XII.

TABLE XX - continued

VARIABLE (1)	LOADING
GLPCMP	.1469
PARTG	.3218
PARTDM	.1523
EMPTHY	.3665
RWDSQ	.0103
RWDSI	.3063
EVAL	.1119
MISSTB	.0899
FREEDA	.0578
TWORK	-.1462
MILCIV	.0517
AGE4	-.3546
AG4XED	-.4369
EMXCOL	.1424
EMXLCP	.2890
EMXPG	.4028
EMXRWQ	.1428
EMXRWI	.3110
EMXEVL	.2626

Substantial relationships are evidenced by canonical loadings greater than or equal to .300 (section 4.3.3.3). Those loadings are underlined.

The dimension on the criterion side might be characterized as high performance since both criteria load heavily on it. However, productivity is somewhat dominant.

It is not so easy to label the dimension on the predictor side since there are so many different kinds of variables with substantial loadings.

Analysis of the canonical loadings in Table XX in conjunction with the two preceding separate analyses of innovation and productivity reveals some recurring results.

The age x education interaction variable (AG4XED) was found to have a negative relationship with the joint criteria. Actually, it has the highest loading of all the 37 predictor variables with the bivariate criteria. The negative relationship of this age x education interaction variable with the criterion set is consistent with the negative relationships this variable has with innovation and productivity separately. Indeed, this variable seems to be a consistent and important predictor of performance.

Two age variables (age and age in four categories - AGE4) both have negative relationships with the joint criteria. These negative relationships with the joint criteria are consistent with the negative relationships that these two age variables both have with innovation and productivity separately.

Education (EDCTN) is negatively related to the bivariate criteria. This negative relationship with the joint criteria is consistent with the negative relationships of education with innovation and productivity separately.

Length of scientific/engineering experience (TSEEXP) and length of Federal Government Employment as a scientist or engineer (TFEDSE) both have negative relationships with the joint criteria. These negative relationships with the joint criteria are consistent with the negative relationships that these two variables both have with innovation and productivity separately. However, it must be remembered that these two variables are highly related with age (r = .924 and r = .738, respectively). Thus, these two variables may be proxy measures of age and telling the same story as the age variable.

Communication with other professionals within the group on technical matters (COMWIG) is consistently related to performance. This communication variable has a positive relationship with the joint criteria, and positive relationships with each criterion separately.

The rewards for innovation variable (RWDSI) is also consistently related to performance. It is positively related to the joint criteria, and positively related to innovation and productivity separately.

The next five variables discussed have substantial relationships with the joint criteria. However, none of these five variables is significantly related to innovation by it-

self. The substantial relationships of these five variables with the joint criteria may be due to their significant relationships with productivity, and the relative dominance of productivity in the joint criteria. Thus, these variables are not as consistently related to performance as are the preceding variables. Hence, the value of these five variables in a joint analysis is debatable. These five variables with their canonical loadings are: empathy x participation on goals interaction (EMXPG)(.4028); empathy (EMPTHY)(.3665); participation on goals (PARTG)(.3218); empathy x rewards for innovation interaction (EMXRWI)(.3110); and Air Force relevancy pressure (RELPRS)(.3041). Their loadings are almost directly proportional to their zero order correlations with productivity (.26, .24, .21, .20, and .19, respectively). This tends to confirm the preceding comments concerning the hypothesized reason for their substantial relationships with the joint criteria, and the relative dominance of productivity in this canonical dimension.

5.2.1.4 Summary of individual level relationships. Analysis of the relationships between the predictor variables and the joint criteria provides a summary of all the preceding relationships. The associations between the predictors and the criteria are systematically summarized in Table XXI. The table contains, for all 37 predictor variables, the significant zero order correlations with both criterion variables, the significant F values from the regression analyses with

innovation and productivity, and the substantial canonical loadings with the bivariate criteria.

TABLE XXI

SUMMARY OF RELATIONSHIPS (N = 154)

VARIABLE[1]	PRODUCTIVITY		INNOVATION		CANONICAL LOADING
	r	F[2]	r	F[2]	
AGE	-.248	(-) 20.2	-.232		-.398
EDCTN	-.195		-.304		-.329
GRADE		(+) 9.1		(+) 10.7	
SCIORE					
TSEEXP	-.192		-.183		-.309
TFEDSE	-.196		-.212		-.319
TINGRP					
TNOTCH					
PROMTG					
COMWIG	.210	(+) 4.1	.161	(+) 8.1	.333
COMOUT					
COMWGL				(-) 6.5	
IPRESS					
QPRESS					
TPRESS					

(1) The abbreviations used are defined in Table XII.

(2) The signs refer to the sign of the beta coefficient.

TABLE XXI - continued

VARIABLE[1]	PRODUCTIVITY		INNOVATION		CANONICAL LOADING
	r	F[2]	r	F[2]	
RELPRS	.192				.304
GLPCMP					
PARTG	.214				.322
PARTDM					
EMPTHY	.237				.367
RWDSI	.199			(+) 4.0	.306
RWDSQ					
EVAL					
FREEDA					
MISSTB					
TWORK					
MILCIV					
NWORKA					
IGHOMO					
AGE4	-.217		-.253		-.355
AG4XED	-.263		-.365	(-) 34.6	-.437
EMXCOL					
EMXLCP	.188				
EMXPG	.264	(+) 11.5			.403
EMXRWQ					
EMXRWI	.203				.311
EMXEVL	.173				

Some variables referenced in Table XXI are consistently related to performance. By consistent is meant, a variable is related to innovation and productivity separately, and related to them jointly.

The age x education interaction variable (AG4XED), age, age(in four categories - AGE4), the two pseudo age variables (length of scientific/engineering experience-TSEEXP, and length of Federal Government Employment as a scientist or engineer-TFEDSE), and education (EDCTN), all are consistently negatively related to performance. The consistent relationships with performance exhibited by this age, education demographic cluster of variables have some interesting implications when compared to other studies. Two studies corrected their measures to covary out the effect of experience: Andrews and Farris (1972); and Pelz and Andrews (1966). Five studies corrected for education: Andrews and Farris (1972); Ellison, et al. (1968); Farris (1969); Pelz (1956); and Pelz and Andrews (1966). The failure to correct for age at the individual level is noteworthy. Of even more importance is the treatment of the experience-education group of variables as noise variables to be covaried out. The implications for selection and assignment of these demographic variables that are related to performance is so obvious that they deserve more attention than noise variables to be covaried out.

Communication with other scientists/engineers within the group (COMWIG) is consistently positively related to

performance at the individual level. This finding is supported by several other research studies. Pelz and Andrews (1966), Pelz (1956), Keeler (1966), Farris (1969), Aram, Morgan and Esbeck (1971), and Kallick (1964) all found significant/ substantial relationships between communication/contact with colleagues and individual performance.

The rewards for innovation variable (RWDSI) is consistently positively related to individual performance. Studies by Keeler (1966), Kallick (1964), McCarrey and Edwards (1973), and Vollmer (1963) support this finding at the individual level.

5.2.2 Group Level Analyses

The variable abbreviations used in the group level analyses are defined in Table XXII.

TABLE XXII

VARIABLE ABBREVIATIONS (N = 35)

ABBREVIATION	VARIABLE
AGE	Age
EDCTN	Educational level
GHETER	Group heterogeneity-technical discipline
GRADE	Grade
TINGRP	Length of group membership
PSCI	Percent of group that is scientists

TABLE XXII - continued

ABBREVIATION	VARIABLE
TSEEXP	Length of scientific/engineering experience
TFEDSE	Length of Federal Government Employment as a scientist or engineer
NWORKA	Number of Work Areas
TNOTCH	Per Cent of Time in nontechnical activities
PROMTG	Frequency of attendance at professional society meetings
COMWIG	Frequency of communication with other professionals within own group on technical matters
COMOUT	Frequency of communication with other professionals outside own group but within laboratory on technical matters
COMWGL	Frequency of communication with group leader on technical matters
QPRESS	Quantity Pressure
IPRESS	Innovation Pressure
TPRESS	Time Pressure
RELPRS	Air Force Relevancy Pressure
GLPCMP	Group leader professional competence
PARTG	Participation on goal setting
PARTDM	Participation on routine decision making
EMPTHY	Group leader's empathy
RWDSQ	Rewards for quantity of output
RWDSI	Rewards for innovation

TABLE XXII - continued

ABBREVIATION	VARIABLE
EVAL	Group leader's evaluation of work
MISSTB	Mission stability
FREEDA	Freedom/autonomy
TWORK	Type of work
PMIL	Percent of group that is military
AGE4	Age in four categories
AG4XED	AGE4 interaction with EDCTN
NWU	Number of Work Units in a group
GRPSIZ	Group size
GRPSZ2	(Group size-average group size)^2
LAB1	Laboratory One
LAB2	Laboratory Two

5.2.2.1 Innovation. Hypotheses were tested using 30 variables[3] (variables numbered one through 27 and 36 through 38 in Table VII) relative to innovation at the group level. The hypotheses and calculated correlations for the 30 predictor variables relative to innovation are contained in Table XXIII.

Only one variable listed in Table XXIII is significantly related to innovation. Communication with other

[3] The laboratory variable, coded LAB1 and LAB2, is viewed as one variable. The titles LAB1 and LAB2 were used instead of LAB A, B and C as in Part IV to preserve the anonymity of the labs.

TABLE XXIII

TESTS OF HYPOTHESES FOR INNOVATION (N = 35)

VARIABLE(1)	H_0(2)	r(3)	p(4)
AGE	0	-.295	N.S.
EDCTN	+	-.144	N.S.
GHETER	+	-.035	N.S.
GRADE	+	-.103	N.S.
PSCI	0	-.069	N.S.
TSEEXP	0	-.263	N.S.
TFEDSE	-	-.289	N.S.
TINGRP	-	-.325	N.S.
TNOTCH	0	-.001	N.S.
PROMTG	+	.076	N.S.
COMWIG	+	.332	.05
COMOUT	+	.091	N.S.
COMWGL	+	-.075	N.S.
IPRESS	+	.017	N.S.
QPRESS	-	-.056	N.S.
TPRESS	+	-.105	N.S.
RELPRS	-	.031	N.S.

(1) The abbreviations used are defined in Table XXII.

(2) + means positively significant, - means negatively significant, 0 means not significant.

(3) For r = .334, p = .05 and for r = .430, p = .01.

(4) N.S. means not significant.

TABLE XXIII - continued

VARIABLE(1)	H_0(2)	r(3)	p(4)
GLPCMP	+	.142	N.S.
PARTG	+	.202	N.S.
PARTDM	+	.021	N.S.
EMPTHY	0	.118	N.S.
RWDSI	+	.175	N.S.
RWDSQ	-	.024	N.S.
EVAL	+	.272	N.S.
FREEDA	0	.013	N.S.
MISSTB	-	-.202	N.S.
TWORK	0	.097	N.S.
NWU	+	-.313	N.S.
GRPSIZ	+	.042	N.S.
LAB1	0	-.167	N.S.
LAB2	0	.172	N.S.

professionals within the group on technical matters (COMWIG) has a positive relationship with innovation (r = .332). This confirmed the hypothesis that a positive linear relationship existed between this communication variable and innovation.

None of the demographic variables listed in Table XXIII that are significantly related to innovation at the individual level are significantly related to innovation at the

group level. Apparently, the process of forming group averages has deleted much of the range associated with these variables and has masked their relationships with innovation.

Twelve variables concerning the group leader (from innovation pressure (IPRESS) through freedom/autonomy (FREEDA) in Table XXIII) were not found to be related to innovation ($p > .05$).

In addition to the 30 variables referenced in Table XXIII, five additional variables were formulated during the data analysis phase. There were no hypotheses associated with these five variables. The five variables and calculated correlations with innovation are listed in Table XXIV.

TABLE XXIV

RESULTS OF FIVE VARIABLES WITH INNOVATION (N = 35)

VARIABLE(1)	r(2)	p(3)
NWORKA	-.434	<.01
PMIL	.293	N.S.
AGE4	-.341	<.05
AG4XED	-.252	N.S.
GRPSZ2	.095	N.S.

(1) The abbreviations used are defined in Table XXII.

(2) For r = .334, p = .05 and for r = .430, p = .01.

(3) N.S. means not significant.

Number of Work Areas (NWORKA) has a significant negative relationship with innovation (r = -.434). It may be recalled that this variable was a count of the different types of work performed, including research, engineering development, system program office support, and other. The relationship indicates that work in a number of different areas is negatively related to innovation. Perhaps, at the group level, this relationship is indicative of the group working in so many areas that it cannot develop enough expertise to be innovative in any of the areas.

The age variable (AGE4) is negatively related to innovation (r = -.341). Whereas this is the only demographic variable related to innovation at the group level, and its associated correlation barely reaches statistical significance, further credence is lent to the supposition that the grouping process has masked the relationships of the demographic variables with innovation.

A summary of the data from the regression is contained in Table XXV.

Number of work areas (NWORKA) is negatively related to innovation once the effects of the other predictors are partialed out. This variable's negative association with innovation is also substantiated by its correlation with innovation (r = -.434).

Communication with other professionals <u>within</u> the group on technical matters (COMWIG) is positively related to

TABLE XXV

STEPWISE REGRESSION ANALYSIS FOR INNOVATION (N = 35)

STEP	VARIABLE(1)	MULTIPLE r	SIGN OF BETA COEFFICIENT	FINAL PARTIAL F(2)
1	NWORKA	.4340	-	4.67
2	COMWIG	.5199	+	15.86
3	COMWGL	.5702	-	9.77
4	LABI	.6510	-	8.82
5	RWDSI	.6890	+	12.58
6	MISSTB	.7442	-	4.83
7	RWDSQ	.7838	-	6.17
8	TINGRP	.8175	-	4.23

(1) The abbreviations used are defined in Table XXII.

(2) $F_{1,26,.95} = 4.23$ and $F_{1,26,.99} = 7.72$

innovation (partial F = 15.86). This is in accordance with the positive relationship of this communication variable and innovation evidenced by the associated significant zero order r. It also confirms this variable's consistently positive relationship with performance noted in the individual level analyses.

Communication with the group leader on technical matters (COMWGL) has a negative relationship with innovation, given the presence of the other predictor variables. This was a surprise because a positive linear relationship between

this communication variable and innovation had been hypothesized. Some possible explanations for the negative relationship are offered in section 5.2.1.1.

The rewards for innovation (RWDSI) variable has a positive relationship with innovation (partial F = 12.58). The positive relationship confirms this variable's consistently positive relationship with performance noted in the individual level analyses.

Rewards for quantity of output (RWDSQ) has a negative association with innovation, once the effects of the other predictor variables are partialed out. Apparently, the group perception of quantity of output (without regard to quality of output) being rewarded is negatively associated with innovation. This negative association confirmed the hypothesis of a negative linear relationship between this variable and innovation.

Mission stability (MISSTB) has a negative relationship with innovation, once the effects of the other predictor variables are partialed out. This negative relationship implies that a group whose mission has changed little, is less innovative. "Plowing the same ground" or "reinventing the same wheel" by definition does not seem to be much of an opportunity for innovation.

Length of group membership (TINGRP) has a negative relationship with innovation (partial F = 4.23). This negative relationship implies that groups, which on the average

have been together a shorter period of time, are more innovative. Groups that take on new members as opposed to long standing groups with relatively constant membership, apparently are more innovative. Perhaps the addition of new members has a stimulating effect.

The Laboratory One (LAB1) variable has a negative relationship with innovation (partial F = 8.82). This negative relationship was surprising since the lab was three organizational levels above the group.

Examination of the residuals did not cause any of the assumptions required for significance testing in regression to be rejected.

Attention was focused on productivity, once the relationships of all the predictor variables with innovation had been analyzed.

5.2.2.2 Productivity. The hypotheses and calculated correlations for 30 predictor variables with productivity at the group level are contained in Table XXVI.

Five predictor variables, all concerning the group leader, are significantly related to group level productivity. Three of these group leader variables have significant relationships with productivity at the individual level.

The rewards for innovation (RWDSI) variable has a positive relationship with group level productivity (r = .406). This rewards variable is consistently positively related to performance as evidenced by this analysis, the group level

TABLE XXVI

TESTS OF HYPOTHESES FOR PRODUCTIVITY (N = 35)

VARIABLE(1)	H_0(2)	r(3)	p(4)
AGE	0	-.142	N.S.
EDCTN	+	.005	N.S.
GHETER	+	.077	N.S.
GRADE	+	-.025	N.S.
PSCI	0	-.055	N.S.
TSEEXP	0	-.154	N.S.
TFEDSE	-	-.182	N.S.
TINGRP	-	-.133	N.S.
TNOTCH	0	.155	N.S.
PROMTG	+	-.119	N.S.
COMWIG	+	.175	N.S.
COMOUT	+	-.223	N.S.
COMWGL	+	-.043	N.S.
IPRESS	-	.276	N.S.
QPRESS	+	.165	N.S.
TPRESS	+	.195	N.S.
RELPRS	0	.227	N.S.

(1) The variable abbreviations are defined in Table XXII.

(2) + means positively significant, - means negatively significant, 0 means not significant.

(3) For r = .334, p = .05 and for r = .430, p = .01.

(4) N.S. means not significant.

TABLE XXVI - continued

VARIABLE(1)	H_0(2)	r(3)	p(4)
GLPCMP	+	.403	<.05
PARTG	+	.416	<.05
PARTDM	+	.309	N.S.
EMPTHY	0	.379	<.05
RWDSI	-	.406	<.05
RWDSQ	+	.205	N.S.
EVAL	+	.480	<.01
FREEDA	0	-.149	N.S.
MISSTB	+	.065	N.S.
TWORK	0	-.040	N.S.
NWU	+	-.300	N.S.
GRPSIZ	+	.023	N.S.
LAB1	0	-.149	N.S.
LAB2	0	.086	N.S.

innovation analysis, and the individual level analyses. Participation on goal setting (PARTG), and the group leader's empathy (EMPTHY), are positively related to productivity (r = .416 and r = .379, respectively). Both of these predictor variables have positive relationships with individual level productivity.

Group leader professional competence (GLPCMP) has a positive relationship with group level productivity (r = .403).

This confirms the associated hypothesis of a positive linear relationship between professional competence of the group leader and the group's productivity.

The group leader's evaluation of the work (EVAL) is positively related to group level productivity (r = .480). This confirms the associated hypothesis of a positive linear relationship between evaluation and productivity.

In addition to the 30 variables referenced in Table XXVI, five additional variables were formulated during the data analysis phase. The five variables and calculated correlations with productivity are listed in Table XXVII.

Little needs to be said, as none of the relationships are significant.

TABLE XXVII

RESULTS OF FIVE VARIABLES WITH PRODUCTIVITY (N = 35)

VARIABLE(1)	r(2)	p(3)
NWORKA	-.284	N.S.
PMIL	.201	N.S.
AGE4	-.161	N.S.
AG4XED	-.006	N.S.
GRPSZ2	-.034	N.S.

(1) The abbreviations used are defined in Table XXII.

(2) For r = .334, p = .05 and for r = .430, p = .01.

(3) N.S. means not significant.

The productivity regression analysis was started with an N = 36. That regression selected only one variable as being related to productivity. Participation on goal setting was found to be positively related to productivity (partial F = 8.27). However, a plot of the residuals on normal probability paper (Appendix I) revealed a departure from normalcy in the residuals. Thus, little confidence was placed in that regression.

The results of the above Ordinary Least Squares Regression were compared with the results from a Robust Regression.[3] The robust technique revealed the presence of an outlier in the data set. Investigation of the data point revealed no errors in measurement, coding, or keypunching, but did reveal the lowest scoring group on productivity of all 36 groups. The point was deleted from the sample and the Ordinary Least Squares Regression was recalculated with an N = 35.

A plot of the residuals due to the Ordinary Least Squares Regression for N = 35 revealed a much closer approximation to normalcy in the residuals (Appendix I). Thus, it was decided to accept the results based on the N = 35 regression.

There was a dramatic change in the regressions due to the deletion of the one point. The multiple correlation

[3] The Robust Regression used is currently under development by A. Paulson and A. Schumaker of RPI as a part of Schumaker's dissertation.

coefficient increased from .442 (for N = 36) to .728 (for N = 35). The number of variables selected by the regression increased from one to five. It appears that the one outlier data point was substantially distorting the results. Thus, little confidence was placed in the N = 36 regression.

Table XXVIII contains a summary of the Ordinary Least Squares Regression for N = 35.

TABLE XXVIII

STEPWISE REGRESSION ANALYSIS FOR PRODUCTIVITY (N = 35)

STEP	VARIABLE (1)	MULTIPLE r	SIGN OF BETA COEFFICIENT	FINAL PARTIAL F (2)
1	EVAL	.4796	+	11.38
2	NWORKA	.5554		
3	COMOUT	.5949		
4	GRADE	.6306	+	7.00
5	TSEEXP	.6830	-	7.95
6	NWU	.7161	-	15.08
7	NWORKA	.6951	(REMOVED)	
8	TNOTCH	.7387	+	5.12
9	COMOUT	.7283	(REMOVED)	

(1) The abbreviations used are defined in Table XXII.

(2) $F_{1,29,.95} = 4.18$ and $F_{1,29,.99} = 7.60$

The group leader's evaluation of the work (EVAL) is positively related to group level productivity (partial F = 11.38). This further supported the associated hypothesis of a positive linear relationship between evaluation and productivity.

Federal Civil Service/Military Grade Level (GRADE) has a positive relationship with productivity (partial F = 7.00). This is analogous to the finding at the individual level wherein grade is positively related to productivity.

The length of scientific/engineering experience (TSEEXP) was found to be negatively related to productivity (partial F = 7.95). This is analogous to the finding at the individual level in which the length of scientific/engineering experience is negatively related to productivity, and innovation and the bivariate criteria. It must also be noted that this variable has a strong relationship with age (.931) and as such is probably a proxy measure of age.

The number of work units is negatively related to productivity (partial F = 15.08). This negative relationship may imply that some groups have so many different pieces of work (work units) that their productivity was inhibited.

The per cent of time in nontechnical activities (TNOTCH) is positively related to productivity (partial F = 5.12). At first glance, this may appear to be puzzling. However, time in nontechnical activities was defined in the questionnaire (Appendix C) to include contract monitoring time. It seems

reasonable that the more time one spent in contract monitoring, the more in-house reports verifying the contractor's work and the more requests for proposals he would produce. This may explain the positive relationship.

For the sake of further comparison, the Robust Regression was also calculated with an N = 35. That analysis revealed the existence of four more possible outliers. No errors in measurement, coding, or keypunching for the four groups were discovered. Three of the points were noteworthy since they were among the lowest scoring groups. The four points were temporarily withdrawn from the sample and the Ordinary Least Squares Regression was performed with an N of 31.

Examination of the residuals (Appendix I) due to the regression based on N = 31 revealed an even closer approximation to normalcy than in the N = 35 regression. The multiple correlation coefficient increased to .841. Five variables were identified with significant relationships with productivity.

Three of the five variables are essentially the same as in the N = 35 regression. The number of work units and the percent of time in nontechnical activities have the same relationships with productivity as exemplified by the N = 35 regression (negative and positive, respectively). The age variable (AGE4) replaced the length of scientific/engineering experience as being negatively related to productivity. It was noted previously that the length of scientific/engineering experience is a proxy measure of age.

The group leader's evaluation of the work and grade were not selected by the N = 31 regression. Instead, the rewards for innovation and the percent of the group that is scientists were selected. The rewards for innovation variable was found to be positively related to productivity (partial F = 7.33). This is in accordance with several earlier findings in which this rewards variable is consistently positively associated with performance. The percent of the group that is scientists was found to be negatively related to productivity (partial F = 4.89). No reason for this finding is obvious.

5.2.2.3 Canonical analysis. At most, 17 predictor variables can be included in the canonical analysis given a sample size of 35 (section 4.3.3.3). A list of 17 predictor variables was used in the multivariate analysis. The list results from the inclusion of those predictor variables that are significantly related to either innovation or productivity in the group level analyses. The list is in Table XXX.

A high relationship between innovation and productivity (r = .680) is noted. The strength of the relationship reinforces the advisability of a multivariate analysis.

A summary of the two canonical roots appears in Table XXIX.

The second canonical root is not discussed further since it is not significant.

The redundancy of the criterion set for the first root is .6855. Thus, more than two-thirds of the variance

TABLE XXIX

CANONICAL ROOTS (N = 35)

ROOTS(1)	CHI SQUARE	d.f.(2)	p
.8191	42.75	18	.001
.5335	19.06	16	.267

(1) The roots = R^2, i.e. the amount of shared variance between the two canonical variate sets.

(2) D.f. means degrees of freedom.

of the criterion variables is shared by the predictor canonical variates.

Table XXX contains the canonical loadings for the one significant canonical root.

Substantial relationships are evidenced by canonical loadings greater than or equal to .300 (section 4.3.3.3). Those loadings are underlined.

The dimension on the criterion side might be characterized as high performance since both criteria load heavily on it.

Titling the dimension on the predictor side is somewhat elusive due to the different kinds of variables with substantial loadings. However, there is a group of five variables dealing with the group leader that have substantial relationships with performance.

TABLE XXX

CANONICAL LOADINGS (N = 35)

VARIABLE[1]	LOADING
PRODUCTIVITY	.9421
INNOVATION	.8867
GRADE	-.0696
TINGRP	-.2571
TSEEXP	-.2403
NWORKA	-.4171
TNOTCH	.1075
COMWIG	.2900
COMWGL	-.0679
AGE4	-.2845
GLPCMP	.3527
PARTG	.3917
EMPTHY	.3234
RWDSQ	.1545
RWDSI	.3718
EVAL	.4716
MISSTB	-.0574
NWU	-.3675
LAB1	-.1882

(1) Table XXII contains the variable abbreviations.

The rewards for innovation (RWDSI) variable has a positive relationship with the joint criteria. This variable is the most consistently related to performance of all the predictor variables. Its positive relationship with performance is evidenced in both the individual and group level analyses.

Four other group leader variables have positive relationships with the joint criteria. The group leader's evaluation of the work (EVAL), participation on goal setting (PARTG), the group leader's empathy (EMPTHY), and the group leader's professional competence (GLPCMP) are all positively related to the bivariate criteria. Their relationships with the joint criteria seem to be due to the strength of their positive relationships with productivity. All four are positively related to productivity and none of the four are related to innovation.

Two other variables are negatively related to the bivariate criteria. Number of work areas (NWORKA) and the number of work units (NWU) are both negatively related to the criterion set. These two variables may both be indicative of the groups working in so many areas or being involved in so many different pieces of work that they are not able to develop their expertise and perform properly.

5.2.2.4 Summary of group level relationships. Analysis of the relationships between the predictor variables and the joint criteria provides a summary of all the preceding relationships. The associations between the predictors and the criteria are systematically summarized in Table XXXI.

TABLE XXXI

SUMMARY OF RELATIONSHIPS (N = 35)

VARIABLE[1]	PRODUCTIVITY		INNOVATION		CANONICAL LOADING
	r	F[2]	r	F[2]	
AGE					
EDCTN					
GHETER					
GRADE		(+) 7.0			
PSCI					
TSEEXP		(-) 8.0			
TFEDSE					
TINGRP				(-) 4.2	
TNOTCH		(+) 5.1			
PROMTG					
COMWIG			.332	(+) 15.9	
COMOUT					
COMWGL				(-) 9.8	
IPRESS					
QPRESS					
TPRESS					
RELPRS					
GLPCMP	.403				.353

(1) The abbreviations are defined in Table XXII.

(2) The signs refer to the sign of the beta coefficient.

TABLE XXXI - continued

VARIABLE[1]	PRODUCTIVITY		INNOVATION		CANONICAL LOADING
	r	F[2]	r	F[2]	
PARTG	.416				.392
PARTDM					
EMPTHY	.379				.323
RWDSI	.406			(+) 12.6	.372
RWDSQ				(-) 6.2	
EVAL	.480	(+) 11.4			.472
FREEDA					
MISSTB				(-) 4.8	
TWORK					
NWU		(-) 15.1			-.368
GRPSIZ					
LAB1				(-) 8.8	
LAB2					
NWORKA			-.434	(-) 4.7	-.417
PMIL					
AGE4			-.341		
AG4XED					
GRPSZ2					

The table contains, for all 35 predictor variables[4], the significant zero order correlations with both criterion variables, the significant F values from the regression analyses with innovation and productivity, and the substantial canonical loadings with the bivariate criteria.

One variable referenced in Table XXXI is consistently related to performance. By consistent is meant, the variable is related to innovation and productivity separately, and related to them jointly. This variable, namely, rewards for innovation (RWDSI) has a consistently positive relationship with performance.

The age-education demographic cluster of variables is not as strongly related to performance at the group level as at the individual level. Apparently, the process of forming group averages has deleted much of the range associated with these variables, and has masked their relationships with performance.

Participation on goal setting and the group leader's empathy deserve special attention. They are the only variables in this research that are so strongly related to one criterion at both the individual and group level of analyses, and not related to the other criterion at either level, that they are also related to the joint criteria at both levels. Participation on goal setting and empathy have positive relationships

[4] The laboratory variable, coded LAB1 and LAB2, is viewed as one variable.

with the joint criteria in both the individual and group level of analyses. However, their relationships seem to be primarily due to the strength of their relationships with productivity. They are significantly positively related to productivity in both levels of analyses. This participation variable and empathy are not related to innovation at either level. An empathy x participation on goal setting interaction term is also positively related to the joint criteria and to productivity at the individual level. This may be indicative of a "genuine" type of participation. The positive relationship of participation with performance is supported by significant/substantial relationships found in other studies by Harrison (1974), Andrews and Farris (1967), and Pelz and Andrews (1966).

PART 6

DISCUSSION AND CONCLUSIONS

6.1 The Measurement of Innovation and Productivity

It was found that the peer ratings were of a reliable nature. Therefore, it is concluded that a substantial degree of agreement existed between the raters in using the definitions and measures of the criterion variables proposed in this research. Innovation was defined as output that is original and useful, and productivity was defined as quantity of output.

Face validity of the criterion measures was implied by the normally shaped distributions of the innovation and productivity scores. Productivity was defined as quantity of output and innovation was viewed as a particular kind or subset of output. Therefore, the finding that the productivity scores are significantly greater than the innovation scores also implied face validity of the criterion measures.

A significant positive relationship between the productivity ratings and number of Air Force Technical Reports and Technical Memorandums was noted in a validation effort.

A strong positive relationship between the innovation and productivity scores was noted. This observed relationship agrees with three other studies cited in the literature that also found strong positive relationships between the two criteria.

Thus, the definitions and peer ratings of innovation and productivity used herein are reliable, possess face validity, and are highly correlated with each other as other studies have found. Therefore, the definitions and the measures have utility in measuring the innovation and productivity of scientists/engineers in an R&D setting.

6.2 Implications of Tested Hypotheses

The temptation arose to retitle this dissertation "Innovation and Productivity: Skinner Revisited". The predictor variable most consistently showing a significant/substantial relationship with performance is rewards for innovation. It is positively related to innovation, and to productivity, and to the joint criteria, at both the individual and group levels. In other words, the individual's perception of this variable is positively related to individual performance, and the group's mean perception of this variable is positively related to group performance. No other predictor variable is so consistently related to performance in this study.

It is important to note that the rewards for innovation variable is positively related to both innovation and productivity. The reason why it is related to both innovation and productivity might be understood by noting the definitions. Productivity is defined as quantity of output, whereas innovation is defined as a particular kind or subset of output. Some productivity is a necessary, although not sufficient condition for innovation. The implication is that if a lab

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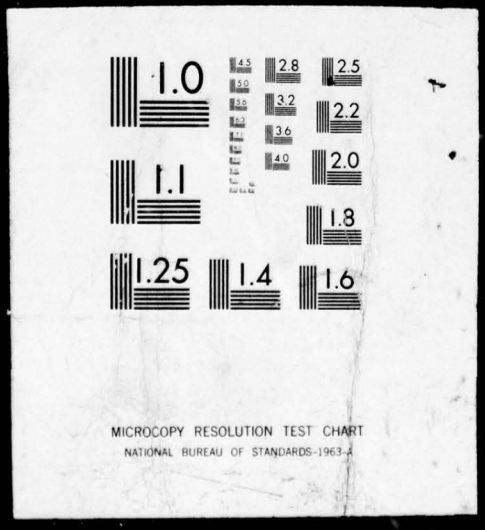

wants innovation (and productivity), then it should reward *innovation*. As Skinner (1971) remarked: "Behavior is shaped and maintained by its consequences." (p.16)

It is also noted that in the Civil Service-Military Systems, the amount of rewards that can be made contingent upon performance is limited. The pay scales are set by Congress and promotions are heavily dependent on seniority. The type of rewards that can be dispensed by the organization/group leader are rewards like recognition for innovation, choice of projects, funded travel to professional society meetings, good performance reports, etc. One is led to two different possible conclusions. Either the rewards variable is so potent a predictor of performance that if rewards like pay and promotion were contingent upon performance then the effect upon performance would be even more marked, or pay and promotion are not important in shaping innovation and productivity. Unfortunately, the answers are unknown because the questionnaire recorded the extent to which the group leader rewarded innovative output, without classifying the types of rewards.

Communication with other professionals <u>within</u> the group on technical matters is consistently related to performance. It is positively related to innovation, productivity and the bivariate criteria at the individual level, as well as to innovation at the group level. This finding appears to lend credence to the concept of stimulation due to contact

with peers. It is also consistent with the findings of several other studies. The implication of encouraging colleague contact is obvious.

Participation on goal setting and the group leader's empathy are both positively related to productivity and to the joint criteria at both the individual and group level. Neither variable is related to innovation. As such, they are the only variables in this study that are so strongly related with one criterion, and not with the other, that the strength of their one criterion relationship carries over to the joint criteria, at both the individual and group levels. It is noted that participation on goal setting interacting with empathy is significantly related to productivity and the joint criteria at the individual level. If the interaction is viewed as a measure of real or genuine participation, the importance of genuine participation, not"going through the motions" variety is underscored.

The age-education cluster of variables is one group of variables consistently related to performance at the individual level. This group of variables consists of the age x education interaction variable, age, age(in four categories), the two pseudo age variables (length of scientific/engineering experience and length of Federal Government Employment as a scientist/engineer) and education. All are negatively related (given the reverse coding of education) to innovation, and to productivity, and to the joint criteria. In fact, the

age x education interaction variable has the strongest relationship of all the predictor variables with innovation, and with the bivariate criteria for the individual level analysis. The variable says that low relative education coupled with high age has a strong negative association with innovation. All the other above age variables and education are associated with low performance, but the combination of age and education in the interaction term is the most important. The interaction may be indicative of an obsolescent type of person whose lack of graduate work as he gets older is indicative of his lack of effort to keep abreast of new developments in a field that is very knowledge oriented. If innovation and productivity are desired outputs, the implication is that older, less educated scientists/engineers belong in different jobs.

Some results are noticeable by their absence of significant relationships. One variable, however, stands out because it is so widely touted in the cookbook "how to create a climate for creativity" R&D Management Literature. No evidence was found, in any of the analyses, that freedom or autonomy is related to either innovation or productivity.

Since both individual perceptions of some organizational variables, and average group perceptions of some organizational variables are significantly related to performance, no further conclusions are offered regarding the relative advantages of the measures.

6.3 Shortcomings of Current Research

As mentioned in the discussion of rewards for innovation, this research was performed in an environment where the amount of rewards that can be made contingent upon performance is limited. The Civil Service System also has other properties not possessed by industry or academia. Thus, an obvious shortcoming is that there were no scientists/engineers from industrial R&D laboratories or university research laboratories in the sample.

The productivity validation was performed by comparing the number of Air Force Technical Reports/Memorandums with the productivity scores. Even though the validation coefficient is significant, it appears from the magnitude of the correlation that more kinds of output, as included in the definition of productivity, should have been included in the productivity validation.

The reliability of the criterion scores is proportional to the number of raters. A number of the criterion scores were based on two raters. Even higher reliability figures could have been obtained if more raters had been used for the ratings.

The small number of groups in the group level analysis (35) restricted the number of variables that could be tested in the group level canonical relationship. More predictor variables could have been tested at the group level with more groups.

Communication with the group leader on technical matters is curiously negatively related to innovation in both the individual and group level regression analyses. Since the content of the communications was not recorded, the reason for this finding is not apparent.

Not all of the data received were used because an individual's data were useless if he was not rated by at least two peers.

6.4 Recommendations for Future Research

The recommendations follow directly from the shortcomings and some problems encountered with the response rate.

This research is begging to be replicated in industrial and university R&D laboratories. Such a replication would provide additional information on the nature of the rewards for innovation relationship with innovation and productivity.

Future studies should classify the types of rewards and check the relationships of the various types of rewards with performance. The consistent importance of rewards being contingent upon innovation mandates further research in this area.

Future productivity validation efforts should include all or most of the items included under output in the definition of productivity.

Studies using the peer rating should use four or five peers as opposed to two or three in order to achieve

even higher reliability figures.

More groups should be included in the group level analysis. This will permit examination of more predictor variables in the group level canonical analysis.

Many of the studies that researched the association of organizational variables and innovation either covaried out age and/or education as if they were extraneous noise variables before beginning the primary analysis or did not even examine them. In this research,age and/or education are among the most important predictor variables at the individual level. Whereas, the organization has some control over these two variables by selection and assignment policies, they are of interest. This comment is particularly relevant in laboratories where there is variance on the education variable. These variables should be included in future research efforts and their relationship with innovation further explored.

The difficulties associated with the response rate strongly indicate that special care needs to be exercised when using peer ratings. Several non-respondees indicated that they would not complete the peer ratings without concrete assurances from laboratory management that the confidentiality of the ratings was guaranteed. Other studies utilizing peer ratings should obtain such assurances. This should increase the response rate and result in more economical use of the data.

A future study should investigate the relationship of communication with the group leader on technical matters with innovation. Particular attention should be devoted to the content of the communications to aid in explaining the relationship.

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APPENDIX

APPENDIX A

PRETEST

QUESTIONNAIRE

Rensselaer Polytechnic Institute

TROY, NEW YORK 12181

SCHOOL OF MANAGEMENT

29 Mar 75

Dear Sir,

We are asking your voluntary cooperation in a study aimed at relating certain organizational variables in various laboratories to the innovation and productivity of the various organizations.

Your responses will be kept in confidence and your anonymity is guaranteed. All data will be reported in aggregate form only.

The study is being conducted as part of the requirements for my doctorate, in association with the Center for Research on Research at Rensselaer Polytechnic Institute. This study in conjunction with several that are being carried out in private laboratories, as well as in other government laboratories, will hopefully be used to develop policy and guidelines that will enhance U.S. technological innovation and output.

Your cooperation in completing and returning this questionnaire is vital to the completion of this work. Thank you for your help in our research.

Sincerely,

Michael J. Stahl

Michael J. Stahl
Capt, USAF
Ph.D. Candidate
Rensselaer Polytechnic Institute

I. PEER RATING FORM

A) Introduction

We are concerned with the work output of Research and Development personnel. Output as used in our research includes:

a. New or improved products;
b. New or improved processes;
c. New or improved techniques;
d. Patents;
e. Patent applications;
f. Published papers in technical or professional journals (or A.F. technical reports);
g. Books;
h. Manuscripts; and
i. Oral presentations to technical or professional audiences.

Effort that is not operationalized or does not result in an end product of some kind (the above list), is not included in the definition of research output. Thus, ideas, thoughts, etc. that are not translated into results are not considered output.

There are at least 2 dimentions of scientific/engineering output which, if analyzed separately, can aid one's understanding of R&D. One dimension is productivity (quantity), and the other is innovativeness (quality of a certain type). Obviously, the 2 can and often do occur together. Hopefully, by analyzing the 2 dimensions separately, the relationship between organizational variables and R&D output can be better understood.

Innovation is defined as output that is original and useful.

Originality refers to output that makes discrete jumps in knowledge, theory, technique or product that was not readily predictable before the fact. At best, non-original output is a continous, somewhat predictable extension of knowledge, theory, technique or product.

Usefulness means that

a. the output adds to the fund of knowledge,
or b. is workable if capable of demonstration and test,
or c. is replicable by other researchers in logic and methodology, even if it apparently conflicts with other knowledge and is years from the point of demonstration and testing.

Originality and usefulness are necessary and sufficient characteristics output must possess to be classified as innovative.

Building upon the previous definition of output, productivity is defined as quantity or amount of output, without regard to innovativeness or any other quality.

B) Branch Rating

(1) Productivity. Viewing productivity as quantity of output, please rate the productivity, over the last 3 years, of the other branches in your division. (Place the appropriate number from the following scale next to the branch's name.)

1 2 3 4 5 6 7 8 9

Zero Productivity - no output in last 3 years.

Outstanding Productivity - exceptional amount of output in last 3 years.

(2) Innovativeness. If you assigned a score greater than 1 on the productivity scale, please rate the innovativeness (originality and usefulness) of the output, over the last 3 years, of the other branch's in your division. (Place the appropriate number from the following scale next to the branch's name.)

If you assigned a score of 1 on the productivity scale, please skip this question.

1 2 3 4 5 6 7 8 9

No Innovativeness - output was not original or had no usefulness.

Outstanding Innovativeness - output was extremely original and useful.

C) Individual Ratings

The following 5 individuals have been randomly selected from your branch. You are asked to rate them on innovation and productivity. Let me assure you that the data will be kept confidential and used for Research purposes only.

(1) Productivity. Viewing productivity as quantity of output, please rate the productivity, over the last 3 years of the following 5 individuals. (Place the appropriate number from the following scale next to their name.)

1	2	3	4	5	6	7	8	9
Zero Productivity - no output in last 3 years.								Outstanding Productivity - exceptional amount of output in last 3 years.

(2) *Innovativeness. If you assigned a score greater than 1 on the* productivity scale, please rate their innovativeness (originality and usefulness) over the last 3 years. (Place the appropriate number from the following scale next to their name.)

If you assigned a score of 1 on the productivity scale, please skip this question.

1	2	3	4	5	6	7	8	9
No Innovativeness - output was not original or had no usefulness.								Outstanding Innovativeness - output was extremely original and useful.

II. ORGANIZATIONAL VARIABLES FORM

A) Please complete the following:

Age (in years using last birthday). _____	Educational level (Circle highest degree). B.S., M.S., Ph.D., Other (please specify) _____
Current Grade (GS level or military grade). ____	Major field of study for highest degree. _____
Years in current branch (round to nearest year). ____	Nature of current work (% of time per category) Engineering development work. _____ Scientific research work. _____ Other (Please specify). _____

Years of scientific/engineering experience (research, consulting, etc.) since first degree (round to nearest year). _____

Years of Federal Government Employment in a scientific/engineering capacity (round to nearest year). _____

Percent of total working time in nontechnical activities (administration, contract monitoring, etc.) _____

Frequency of attendance at national or international professional society meetings (number of meetings per year). _____

Your frequency of communication with:
(a) other scientists/engineers within own branch on technical matters (number of contacts per week - round to nearest number). _____
(b) other scientists/engineers outside own branch but within your laboratory on technical matters (number of contacts per week - round to nearest number). _____
(c) branch chief on technical matters (number of contacts per week - round to nearest number). _____

B) Please complete the following by placing a check mark or X above what you feel is the appropriate category.

1. What amount of pressure is exerted upon you by your branch chief for:
   (a) Quantity of output.

1	2	3	4	5	6	7	8	9
No Pressure -quantity of output never mentioned.								Extensive Pressure - quantity of output always stressed.

   (b) Innovative (original and useful) output.

1	2	3	4	5	6	7	8	9
No Pressure -innovative output never mentioned.								Extensive Pressure - innovative output always stressed.

(c) Meeting deadlines and schedules.

1	2	3	4	5	6	7	8	9
No Pressure - deadlines and schedules never mentioned.								Extensive Pressure - deadlines and schedules always stressed.

(d) Relevancy of your work to the Air Force Mission.

1	2	3	4	5	6	7	8	9
No Pressure - relevancy of work to AF Mission never mentioned.								Extensive Pressure - relevancy of work to AF Mission always stressed.

2. How would you rate the professional competence (i.e. skill in his own technical speciality) of your branch chief?

1	2	3	4	5	6	7	8	9
Absolute Incompetence - either no skill or extreme obsolescence.								Extreme Competence- truly outstanding and current in his speciality.

3. Extent of participation with branch chief on:
   (a) Goal setting (including project selection) concerning my work.

1	2	3	4	5	6	7	8	9
No Participation - I either set my own goals or they are set for me.								Total Participation - branch chief always actively shares this function with me.

(b) Routine decision making concerning my work.

1	2	3	4	5	6	7	8	9
No Participation - I either make all decisions concerning my work or they are made for me.								Total Participation - branch chief always actively shares this function with me.

4. Extent of branch chief's empathy (i.e. understands my feelings).

1	2	3	4	5	6	7	8	9
No Empathy -He never understands my feelings.								Complete Empathy - he always deeply understands my feelings.

5. Extent to which branch chief rewards:
   (a) Quantity of Output.

1	2	3	4	5	6	7	8	9
Never - he never rewards quantity of output.								Always - he always provides meaningful rewards for quantity of output.

   (b) Innovative (original and useful) output.

1	2	3	4	5	6	7	8	9
Never - he never rewards innovative output.								Always - he always provides meaningful rewards for innovative output.

6. How thorough is your branch chief in his evaluation of your work?

1	2	3	4	5	6	7	8	9
No Evaluation - branch chief never evaluates my work.								Total Evaluation - branch chief always evaluates my work in detail.

7. How stable has the branch's <u>mission</u> been over the past 3 years?

1	2	3	4	5	6	7	8	9
No Stability - mission totally changed.								Absolute Stability - no change in mission.

8. Extent of freedom/autonomy from branch chief concerning my work.

1	2	3	4	5	6	7	8	9
No Freedom - branch chief exerts absolute control over my work.								Total Freedom - branch chief exerts no control over my work.

APPENDIX B

GROUP LEADER

QUESTIONNAIRE

The cover letter for this questionnaire was the same as the cover letter for the Revised Questionnaire (Appendix C).

Please complete the following:

1. Age (in years using last birthday). _____

2. Educational level (Circle highest degree).
   B.S. M.S. Ph.D. Other (please specify) _____

3. Years in current group leader position (round to nearest year.) _____

4. Major field of study for highest degree. _____

5. Turnover is expressed as a ratio of the number of scientists/engineers who have left your group in the past 2 years to the average number of scientists/engineers in your group during that time. What has been the per cent turnover of scientists/engineers for your group in the past 2 years? _____

6. Years your group has been working in this technical area (neglecting semantic changes) (round to the nearest year). _____

7. FY 75 dollar budget as % of FY 73 dollar budget for your group. _____

8. Number of authorized scientists and engineers in FY 75 as % of number of authorized scientists and engineers in FY 73 for your group. _____

APPENDIX C

REVISED QUESTIONNAIRE

School of Management

Rensselaer Polytechnic Institute Troy, New York 12181

2 Jun 75

Dear Sir,

I am asking your voluntary cooperation in a study aimed at relating certain organizational variables in various laboratories to the innovation and productivity of the various organizations.

Your responses will be kept in confidence and your anonymity is guaranteed. All data will be reported in aggregate form only. I have put a code number on your questionnaire only for control purposes. No one else has access to the code or the data.

The study is being conducted as part of the requirements for my doctorate, in association with the Center for Research on Research at Rensselaer Polytechnic Institute. This study in conjunction with several that are being carried out in private laboratories, as well as in other government laboratories, will hopefully add to the fund of knowledge concerning organizational variables associated with the innovation and productivity of R&D organizations.

I use the terms group and group leader in the questionnaire. Some laboratories use the terms technical areas and/or technical area managers instead. Which ever terms are appropriate, please think in terms of your immediate formal work group and immediate supervisor.

Your cooperation in completing and returning this questionnaire within 3 weeks is vital to the completion of this work . Thank you for your help in my research.

Sincerely,

Michael J. Stahl, Capt, USAF
Ph.D. Candidate
Rensselaer Polytechnic Institute

USAF SCN 75-140

I. PEER RATING FORM

A) Introduction. The following definitions are used throughout the questionnaire.

1. OUTPUT (of Research and Development personnel) includes:
   a. New or improved products;
   b. New or improved processes;
   c. New or improved techniques;
   d. Patents;
   e. Patent applications;
   f. Published papers in technical or professional journals (or A.F. technical reports/memorandums);
   g. Books;
   h. Manuscripts;
   i. Oral presentations to technical or professional audiences; and
   j. Requests for proposals.

Effort that is not operationalized or does not result in an end product of some kind (the above list), is not included in the definition of research output. Thus, ideas, thoughts, etc., that are not translated into results are not considered output.

2. INNOVATION: Output that is original and useful. Originality and usefulness are necessary and sufficient characteristics output must possess to be classified as innovative. Innovativeness may be viewed as a quality dimension of output.

a. ORIGINAL: The output makes discrete jumps in knowledge, theory, technique or product that was not readily predictable before the fact. At best, non-original output is a continuous somewhat predictable extension of knowledge, theory, technique or product.

b. USEFUL: The output
   i. adds to the fund of knowledge,
   or ii. is workable if capable of demonstration and test,
   or iii. is replicable by other researchers in logic and methodology, even if it apparently conflicts with other knowledge and is years from the point of demonstration and test. Thus, usefulness is broader in scope than payoff or immediate usefulness to the Air Force.

3. PRODUCTIVITY: Quantity or amount of output, without regard to innovativeness or any other quality. Productivity may be viewed as a quantity dimension of output.

B) Individual Ratings

The following individuals have been randomly selected from your group. You are asked to rate them on innovation and productivity. Let me assure you that the data will be kept confidential and used for research purposes only here at RPI.

(1) Productivity. Viewing productivity as quantity of output, please rate the productivity, over the last 2 years of the following individuals. If you or they have been in the group for less than 2 years, please indicate the time period over which you are rating them. (Place the appropriate number from the following scale next to their name.)

1	2	3	4	5	6	7	8	9
Zero Productivity - no output in last 2 years.								Outstanding Productivity - exceptional amount of output in last 2 years.

(2) Innovativeness. If you assigned a score of 1 on the productivity scale, please do not rate the individual on this question. If you assigned a score greater than 1 on the productivity scale, please rate their innovativeness (originality and usefulness) over the last 2 years. If you or they have been in the group for less than 2 years, please indicate the time period over which you are rating them. (Place the appropriate number from the following scale next to their name.)

1	2	3	4	5	6	7	8	9
No Innovativeness - output was not original or had no usefulness.								Outstanding Innovativeness - output was extremely original and useful.

II. ORGANIZATIONAL VARIABLES FORM

A) Please complete the following:

Age(in years using last birthday). _____	Educational level(Circle highest degree). B.S.,M.S.,Ph.D, Other(please specify)_____
Current Grade(GS level or military grade).____	Major field of study for highest degree. _____
Years in current group(round to nearest year). _____	Nature of current work(% of time per category) Research _____ Engineering Development _____ System Program Office Support _____ Other (please specify) _____

Years of scientific/engineering experience(research, consulting, etc.) since first degree(round to nearest year). _____

Years of Federal Government Employment in a scientific/engineering capacity (round to nearest year). _____

Percent of total working time in nontechnical activities(administration, contract monitoring, etc.) _____

Frequency of attendance at national or international professional society meetings (number of meetings per year). _____

Your frequency of communication with:
(a) other scientists/egnineers within own group on technical matters (number of contacts per week- round to nearest number). _____
(b) other scientists/engineers outside own group but within your laboratory on technical matters (number of contacts per week- round to nearest number). _____
(c) group leader on technical matters (number of contacts per week - round to nearest number). _____

B) Please complete the following by placing a check mark or X above what you feel is the appropriate category.

1. What amount of pressure is exerted upon you by your group leader for:
   (a) Quantity of output.

1	2	3	4	5	6	7	8	9
No Pressure - quantity of output never mentioned.								Extensive Pressure- quantity of output always stressed.

   (b) Innovative (original and useful) output.

1	2	3	4	5	6	7	8	9
No Pressure - innovative output never mentioned.								Extensive Pressure- innnovative output always stressed.

(c) Meeting deadlines and schedules.

1	2	3	4	5	6	7	8	9
No Pressure - deadlines and schedules never mentioned.								Extensive Pressure - deadlines and schedules always stressed.

(d) Relevancy of your work to the Air Force Mission.

1	2	3	4	5	6	7	8	9
No Pressure - relevancy of work to AF Mission never mentioned.								Extensive Pressure - relevancy of work to AF Mission always stressed.

2. How would you rate the professional competence(i.e. skill in his own technical speciality) of your group leader?

1	2	3	4	5	6	7	8	9
Absolute Incompetence -either no skill or extreme obsolescence.								Extreme Competence - truly outstanding and current in his speciality.

3. Extent of participation with group leader on:
(a) Goal setting(including project selection) concerning my work.

1	2	3	4	5	6	7	8	9
No Participation - I set my own goals or they are set for me.								Total Participation- he always actively shares this function with me.

(b) Routine decision making concerning my work.

1	2	3	4	5	6	7	8	9
No Participation -I either make all decisions concerning my work or they are made for me.								Total Participation - he always actively shares this function with me.

4. Extent of group leader's empathy (i.e. understands my feelings).

1	2	3	4	5	6	7	8	9
No Empathy - he never understands my feelings.								Complete Empathy -he always deeply understands my feelings.

5. Extent to which group leader rewards:
   (a) Quantity of Output.

1	2	3	4	5	6	7	8	9
Never- he never rewards quantity of output.								Always - he always provides meaningful rewards for quantity of output.

   (b) Innovative (original and useful) output.

1	2	3	4	5	6	7	8	9
Never - he never rewards innovative output.								Always- he always provides meaningful rewards for innovative output.

6. How thorough is your group leader in his evaluation of your work?

1	2	3	4	5	6	7	8	9
No Evaluation - he never evaluates my work.								Total Evaluation - he always evaluates my work in detail.

7. How stable has the group's mission been over the past 2 years?

1	2	3	4	5	6	7	8	9
No Stability - mission totally changed.								Absolute Stability - no change in mission.

8. Extent of freedom/autonomy from group leader concerning my work.

1	2	3	4	5	6	7	8	9
No Freedom- he exerts absolute control over my work.								Total Freedom - he exerts no control over my work.

APPENDIX D

FOLLOW-UP LETTER

School of Management

Rensselaer Polytechnic Institute Troy, New York 12181

23 Jun 75

Dear Sir,

In this follow-up to my 2 Jun 75 letter, I am again asking for your voluntary cooperation. Due to the nature of the questions, YOU AND ONLY YOU can provide the data that I need for my dissertation. Unquestionably, the research can not be completed with the current very low response rate.

Your responses will be kept in confidence and your anonymity is guaranteed. All data will be reported in aggregate form only. I have put a code number on your questionnaire solely for control purposes. No one else has access to the code or the data.

The questionnaire has been approved by USAF as evidenced by the Survey Control Number on the bottom. No one in USAF (other than myself) is sponsoring this research and no one shall have access to the data.

The study is being conducted as part of the requirements for my doctorate, in association with the Center for Research on Research at Renesselaer Polytechnic Institute. This study in conjunction with several that are being carried out in private laboratories, as well as in other government laboratories, will hopefully add to the fund of knowledge concerning organizational variables associated with the innovation and productivity of R&D organizations.

Your cooperation in completing and returning this questionnaire within 3 weeks is vital to the completion of this work. Thank you for your help in my research.

I'm sorry to bother you if our letters cross in the mail.

Sincerely,

Michael J. Stahl

Michael J. Stahl,Capt,USAF
Ph.D. Candidate
Rensselaer Polytechnic Institute

P.S. My telephone number is: A.C. 518, 237-0645.

USAF SCN 75-140

APPENDIX E

MEANS, STANDARD DEVIATIONS

AND

CORRELATION MATRIX

FOR N = 154

VARIABLE (1)	MEAN	STANDARD DEVIATION
AGE	35.7	9.19
EDCTN	2.3	0.70
IGHOMO	0.6	0.49
GRADE	3.3	0.81
TINGRP	5.3	4.70
SCIORE	0.2	0.41
TSEEXP	11.3	7.88
TFEDSE	9.3	6.96
NWORKA	2.4	0.92
TNOTCH	28.0	23.13
PROMTG	0.9	0.93
COMWIG	12.9	16.19
COMOUT	4.9	8.95
COMWGL	3.3	3.61
QPRESS	4.0	1.98
IPRESS	3.8	2.09
TPRESS	5.7	2.04
RELPRS	5.9	2.14
GLPCMP	6.5	1.82
PARTG	5.0	2.27
PARTDM	3.9	2.06
EMPTHY	6.0	1.93
RWDSQ	4.9	2.11
RWDSI	5.2	2.31

(1) The variable abbreviations are defined in Table XII.

VARIABLE	MEAN	STANDARD DEVIATION
EVAL	5.2	2.04
MISSTB	5.8	2.28
FREEDA	6.8	1.48
TWORK	1.1	0.65
MILCIV	0.2	0.40
AGE4	2.1	0.93
AG4XED	4.9	2.99
EMXCOL	21.0	26.29
EMXLCP	40.4	18.68
EMXPG	31.9	19.64
EMXRWQ	31.2	18.49
EMXRWI	33.6	20.34
EMXEVL	32.9	18.32
INNOVATION	5.4	1.53
PRODUCTIVITY	5.9	1.46

CORRELATION MATRIX-PREDICTOR VARIABLES (N = 154) (2)

	AGE	EDCTN	IGHOMO	GRADE	TINGRP	SCIORE	TSEEXP	TFEDSE	NWORKA	TNOTCH
AGE	1.000	.154	-.249	.657	.425	.175	.924	.738	.072	.026
EDCTN		1.000	-.104	-.068	.209	-.042	.140	.213	.038	.020
IGHOMO			1.000	-.026	-.012	-.428	-.211	-.248	.009	-.113
GRADE				1.000	.478	.089	.706	.662	.053	.035
TINGRP					1.000	.030	.444	.578	.236	-.031
SCIORE						1.000	.152	.131	.044	-.023
TSEEXP							1.000	.787	.037	.053
TFEDSE								1.000	.162	.055
NWORKA									1.000	.042
TNOTCH										1.000

(2) For r = .158, p = .05 and for r = .207, p =.01.

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PROMTG	COMWIG	COMOUT	COMWGL	QPRESS	IPRESS	TPRESS	RELPRS	GLPCMP	PARTG
AGE	.031	-.066	.015	-.002	-.051	-.029	-.022	-.002	.030	.018
EDCTN	-.130	-.062	-.013	-.097	.060	.038	.015	-.127	.056	-.052
IGHOMO	.079	-.090	-.171	-.010	.102	.175	.094	.196	.072	-.018
GRADE	.097	.017	.131	.057	-.105	-.038	-.014	.089	-.075	-.001
TINGRP	-.102	.032	.068	.024	.099	.060	.125	.066	-.068	.030
SCIORE	.008	-.040	-.003	.048	.097	.039	.134	.115	-.077	.127
TSEEXP	.039	-.035	.072	-.019	-.126	-.040	-.093	-.032	-.011	.020
TFEDSE	.061	-.071	.104	-.047	-.060	-.036	-.008	-.022	-.069	-.016
NWORKA	.006	-.020	.116	-.033	.032	-.074	.163	.040	-.192	-.174
TNOTCH	-.007	.074	.068	.166	.065	.083	.093	.014	.035	.086

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PARTDM	EMPTHY	RWDSQ	RWDSI	EVAL	MISSTB	FREEDA	TWORK	MILCIV	AGE4
AGE	-.024	.051	.017	-.001	.018	-.011	-.007	.081	-.382	.946
EDCTN	-.069	-.110	-.026	.029	-.019	-.046	-.119	-.165	-.244	.133
IGHOMO	.070	.025	.052	.076	.028	-.023	.151	-.121	.156	-.230
GRADE	-.138	.085	-.058	-.030	-.123	-.089	.114	.099	-.407	.622
TINGRP	-.092	.026	-.122	-.061	-.012	-.053	-.042	.003	-.346	.428
SCIORE	.054	.144	.036	.092	.077	.085	-.073	.100	-.217	.109
TSEEXP	-.093	.084	.030	-.012	-.040	-.021	.073	.053	-.394	.860
TFEDSE	-.109	-.014	-.054	-.058	-.088	-.045	.005	.066	-.355	.704
NWORKA	-.074	-.076	.000	-.014	-.020	-.126	-.011	-.102	-.054	.105
TNOTCH	.021	.015	.131	.072	.027	.074	.046	-.012	-.061	.046

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	AG4XED	EMXCOL	EMXLCP	EMXPG	EMXRWQ	EMXRWI	EMXEVL
AGE	.826	.003	.059	.025	.051	.004	.025
EDCTN	.595	-.135	-.026	-.106	-.086	-.046	-.090
IGHOMO	-.246	.004	.026	-.006	.020	.042	.036
GRADE	.447	.073	.035	.034	.018	.036	-.035
TINGRP	.438	.024	-.020	.019	-.081	-.050	-.023
SCIORE	.074	.080	.085	.157	.120	.146	.128
TSEEXP	.754	-.004	.064	.044	.072	.040	.007
TFEDSE	.675	-.035	-.025	-.028	-.035	-.036	-.067
NWORKA	.097	-.050	-.150	-.182	-.054	-.042	-.096
TNOTCH	.076	.149	.038	.067	.088	.059	.014

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PROMTG	COMWIG	COMOUT	COMWGL	QPRESS	IPRESS	TPRESS	RELPRS	GLPCMP	PARTG
PROMTG	1.000	.055	.173	-.025	-.040	.058	.068	.109	.033	-.036
COMWIG		1.000	.598	.490	.006	.132	-.060	.063	.153	.106
COMOUT			1.000	.425	-.097	-.052	-.176	-.029	.022	-.060
COMWLG				1.000	.148	.183	-.011	.082	.377	.240
QPRESS					1.000	.503	.501	.338	.249	.423
IPRESS						1.000	.357	.435	.382	.460
TPRESS							1.000	.464	.180	.257
RELPRS								1.000	.182	.401
GLPCMP									1.000	.381
PARTG										1.000

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PARTDM	EMPTHY	RWDSQ	RWDSI	EVAL	MISSTB	FREEDA	TWORK	MILCIV	AGE4
PROMTG	-.089	.058	.025	.041	-.078	-.096	.154	.070	-.010	.035
COMWIG	.043	.075	-.073	.009	.020	.045	.041	.032	-.001	-.040
COMOUT	-.089	.049	-.058	-.022	-.115	.054	.113	.008	-.091	.022
COMWGL	.165	.194	.191	.241	.254	.183	.133	-.009	-.003	.036
QPRESS	.229	-.003	.152	.135	.328	.081	-.309	-.068	.000	-.031
IPRESS	.383	.293	.254	.381	.358	.169	-.035	.097	-.017	-.058
TPRESS	.100	.132	.237	.273	.387	.051	-.120	-.158	.023	-.034
RELPRS	.184	.222	.178	.255	.316	-.056	-.077	-.025	.055	-.029
GLPCMP	.224	.470	.400	.448	.486	.256	.024	-.092	.051	.051
PARTG	.520	.404	.254	.351	.546	.155	-.050	-.095	.064	.021

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	AG4XED	EMXCOL	EMXLCP	EMXPG	EMXRWQ	EMXRWI	EMXEVL
PROMTG	-.045	-.012	.041	-.017	.014	.028	-.038
COMWIG	-.056	.460	.138	.109	-.021	.040	.046
COMOUT	.015	.412	.064	-.024	-.029	-.002	-.059
COMWGL	-.002	.957	.351	.280	.237	.269	.282
QPRESS	.027	.104	.126	.270	.107	.092	.177
IPRESS	-.018	.238	.390	.456	.266	.364	.373
TPRESS	-.022	.003	.185	.200	.221	.243	.303
RELPRS	-.092	.128	.232	.372	.167	.227	.298
GLPCMP	.080	.424	.801	.492	.473	.510	.558
PARTG	.027	.316	.489	.888	.354	.410	.529

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PARTDM	EMPTHY	RWDSQ	RWDSI	EVAL	MISSTB	FREEDA	TWORK	MILCIV	AGE4
PARTDM	1.000	.235	.193	.298	.435	.145	-.111	-.050	.101	-.025
EMPTHY		1.000	.490	.548	.451	.321	.238	.037	-.015	.058
RWDSQ			1.000	.810	.577	.271	.151	-.099	.036	.046
RWDSI				1.000	.614	.260	.124	-.065	-.045	.004
EVAL					1.000	.289	-.046	-.127	.095	.043
MISSTB						1.000	.064	-.156	.020	.008
FREEDA							1.000	-.063	.066	-.030
TWORK								1.000	-.121	.075
MILCIV									1.000	-.358
AGE4										1.000

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	AG4XED	EMXCOL	EMXLCP	EMXPG	EMXRWQ	EMXRWI	EMXEVL
PARTDM	-.049	.221	.246	.469	.211	.279	.409
EMPTHY	.004	.379	.862	.715	.763	.777	.774
RWDSQ	.020	.284	.527	.393	.901	.761	.630
RWDSI	.012	.340	.603	.484	.798	.917	.687
EVAL	.040	.326	.566	.544	.601	.620	.867
MISSTB	.007	.263	.331	.270	.348	.340	.376
FREEDA	-.077	.194	.190	.110	.202	.171	.119
TWORK	-.029	.008	-.018	-.056	-.028	-.013	-.063
MILCIV	-.355	.005	-.005	.048	.038	-.011	.073
AGE4	.852	.044	.076	.027	.079	.055	.041

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	AG4XED	EMXCOL	EMXLCP	EMXPG	EMXRWQ	EMXRWI	EMXEVL
AG4XED	1.000	-.017	.061	-.004	.023	.024	-.003
EMXCOL		1.000	.504	.435	.387	.419	.443
EMXLCP			1.000	.737	.749	.790	.809
EMXPG				1.000	.595	.644	.727
EMXRWQ					1.000	.905	.796
EMXRWI						1.000	.821
EMXEVL							1.000

APPENDIX F

MEANS, STANDARD DEVIATIONS

AND

CORRELATION MATRIX

FOR N = 35

VARIABLE (1)	MEAN	STANDARD DEVIATION
AGE	35.7	5.56
EDCTN	2.4	0.39
GHETER	2.3	0.87
GRADE	3.2	0.61
TINGRP	5.3	3.33
PSCI	0.2	0.25
TSEEXP	11.2	4.77
TFEDSE	9.3	4.46
NWORKA	2.4	0.58
TNOTCH	28.1	13.82
PROMTG	0.9	0.54
COMWIG	12.8	8.02
COMOUT	4.8	3.63
COMWGL	3.2	1.74
QPRESS	4.0	1.24
IPRESS	3.8	1.05
TPRESS	5.7	1.20
RELPRS	6.0	1.14
GLPCMP	6.4	1.10
PARTG	5.0	1.31
PARTDM	3.9	1.07
EMPTHY	5.8	1.16
RWDSQ	4.8	1.12
RWDSI	5.1	1.34

(1) The Variable abbreviations are defined in Table XXII.

VARIABLE[1]	MEAN	STANDARD DEVIATION
EVAL	5.1	1.02
MISSTB	5.7	1.55
FREEDA	6.9	0.85
TWORK	1.1	0.65
PMIL	0.2	0.22
AGE4	2.0	0.53
AG4XED	5.0	1.73
NWU	9.4	5.97
GRPSIZ	5.3	1.62
GRPSZ2	2.6	3.67
LAB1	0.4	0.50
LAB2	0.2	0.43
INNOVATION	5.4	0.88
PRODUCTIVITY	5.9	0.86

CORRELATION MATRIX-PREDICTOR VARIABLES(N = 35) (2)

	AGE	EDCTN	GHETER	GRADE	TINGRP	PSCI	TSEEXP	TFEDSE	NWORKA	TNOTCH
AGE	1.000	.284	.187	.734	.534	.310	.931	.757	.280	.148
EDCTN		1.000	-.079	-.003	.424	-.038	.185	.167	.037	-.073
GHETER			1.000	.229	.279	.295	.202	.360	-.025	.083
GRADE				1.000	.535	.193	.773	.768	.289	.281
TINGRP					1.000	.078	.544	.706	.337	-.037
PSCI						1.000	.381	.338	-.010	.070
TSEEXP							1.000	.834	.161	.123
TFEDSE								1.000	.220	.274
NWORKA									1.000	.200
TNOTCH										1.000

(2) For r = .334, p = .05 and for r = .430, p = .01.

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PROMTG	COMWIG	COMOUT	COMWGL	QPRESS	IPRESS	TPRESS	RELPRS	GLPCMP	PARTG
AGE	-.103	-.111	.031	.027	.020	-.123	.001	.028	-.007	.018
EDCTN	-.359	.005	-.053	-.054	.332	.173	.079	.028	.186	.226
GHETER	-.260	.083	.182	.020	-.141	-.185	-.081	-.158	.013	.118
GRADE	.010	-.025	.232	.081	-.185	-.245	.034	.043	-.105	-.174
TINGRP	-.298	-.099	-.021	-.141	-.030	-.077	.177	.109	-.110	-.155
PSCI	-.005	.057	.045	.135	.241	-.027	.147	.125	.002	.277
TSEEXP	-.041	-.009	.150	.036	-.099	-.263	-.080	-.015	-.086	.011
TFEDSE	-.008	-.161	.208	-.038	-.109	-.276	.011	.017	-.167	-.069
NWORKA	-.098	-.111	.055	.111	.172	.112	.320	.222	-.159	-.174
TNOTCH	.109	-.199	-.037	.138	.172	.299	.191	.392	.004	.178

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PARTDM	EMPTHY	RWDSQ	RWDSI	EVAL	MISSTB	FREEDA	TWORK	PMIL	AGE4
AGE	-.036	.211	.057	.070	-.071	.065	.116	-.216	-.578	.967
EDCTN	.088	.112	-.049	.048	.101	-.009	-.323	-.158	-.445	.313
GHETER	-.016	.405	.125	.166	.121	.354	-.239	.015	-.228	.216
GRADE	-.317	.118	.016	-.026	-.185	-.066	.196	.047	-.601	.705
TINGRP	-.338	.036	-.111	-.031	-.226	-.086	-.140	.033	-.602	.505
PSCI	.097	.337	.320	.330	.179	.217	-.161	.028	-.310	.229
TSEEXP	-.141	.167	.077	.032	-.139	.021	.169	-.191	-.580	.894
TFEDSE	-.264	.060	.083	.024	-.268	-.012	.102	-.062	-.669	.716
NWORKA	-.003	-.067	.116	.092	-.007	.020	.179	.123	-.202	.272
TNOTCH	.089	.180	.280	.237	.071	.078	.213	.336	-.177	.171

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	AG4XED	NWU	GRPSIZ	GRPSZ2	LAB1	LAB2
AGE	.766	.043	.057	.115	.042	-.058
EDCTN	.569	-.067	-.066	-.042	.125	.033
GHETER	.114	.325	.283	.001	-.010	-.296
GRADE	.479	.272	.233	.253	-.226	-.080
TINGRP	.491	.245	.256	.168	.135	-.313
PSCI	.125	.047	.081	.017	-.147	.091
TSEEXP	.675	-.017	.051	.130	-.016	-.075
TFEDSE	.581	.238	.132	.177	-.080	-.198
NWORKA	.280	.562	.130	.124	-.115	-.050
TNOTCH	.204	.505	-.167	-.083	-.590	.081

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PROMTG	COMWIG	COMOUT	COMWGL	QPRESS	IPRESS	TPRESS	RELPRS	GLPCMP	PARTG
PROMTG	1.000	-.044	.158	.292	-.127	.079	-.015	.102	.117	-.022
COMWIG		1.000	.562	.555	-.002	-.003	-.318	-.118	.366	.268
COMOUT			1.000	.509	-.363	-.298	-.563	-.318	.044	.004
COMWGL				1.000	.169	.261	-.191	.000	.538	.300
QPRESS					1.000	.632	.620	.549	.368	.495
IPRESS						1.000	.567	.655	.426	.528
TPRESS							1.000	.694	.092	.338
RELPRS								1.000	.271	.367
GLPCMP									1.000	.555
PARTG										1.000

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PARTDM	EMPTHY	RWDSQ	RWDSI	EVAL	MISSTB	FREEDA	TWORK	PMIL	AGE4
PROMTG	.036	.091	.164	.124	.034	-.085	.306	.099	.164	-.088
COMWIG	.144	.209	.160	.104	.364	.104	-.144	.095	.233	-.060
COMOUT	-.164	.106	.223	.048	.010	.077	.184	.066	-.176	.124
COMWGL	.263	.316	.313	.288	.359	.313	.004	.051	-.057	.107
QPRESS	.534	.174	.203	.379	.474	.147	-.419	-.002	-.082	.004
IPRESS	.515	.321	.253	.501	.531	.197	-.193	.067	.110	-.089
TPRESS	.343	.122	.120	.363	.305	.126	-.331	.158	-.015	-.085
RELPRS	.209	.230	.244	.431	.439	-.003	-.258	.184	-.046	-.018
GLPCMP	.482	.511	.277	.412	.546	.300	-.330	-.039	.065	.020
PARTG	.606	.570	.465	.643	.651	.295	-.313	.043	.006	.001

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	AG4XED	NWU	GRPSIZ	GRPSZ2	LAB1	LAB2
PROMTG	-.150	.024	.096	.205	-.260	.364
COMWIG	-.066	-.028	.221	.127	-.054	.016
COMOUT	.033	.240	.183	.126	-.286	.153
COMWGL	.017	.221	.037	-.022	-.362	.136
QPRESS	.232	.152	-.068	-.025	.115	.054
IPRESS	.009	.166	-.107	.180	-.018	.202
TPRESS	-.019	.254	.149	.019	.108	.124
RELPRS	.078	.260	.101	.013	-.134	.276
GLPCMP	.163	.002	.036	-.197	.023	.059
PARTG	.051	-.095	-.138	-.158	-.005	.249

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	PARTDM	EMPTHY	RWDSQ	RWDSI	EVAL	MISSTB	FREEDA	TWORK	PMIL	AGE4
PARTDM	1.000	.326	.345	.562	.681	.449	-.379	-.234	.179	-.014
EMPTHY		1.000	.634	.710	.583	.448	-.153	-.029	-.135	.269
RWDSQ			1.000	.842	.589	.381	.058	.010	-.124	.052
RWDSI				1.000	.755	.356	-.166	-.041	-.156	.047
EVAL					1.000	.433	-.399	-.124	.130	-.043
MISSTB						1.000	-.086	-.371	.100	.123
FREEDA							1.000	-.005	.134	.102
TWORK								1.000	-.053	-.245
PMIL									1.000	-.551
AGE4										1.000

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	AG4XED	NWU	GRPSIZ	GRPSZ2	LAB1	LAB2
PARTDM	.076	-.076	-.075	-.157	.058	.125
EMPTHY	.198	.115	.206	.041	-.152	.238
RWDSQ	.094	.117	.146	.056	-.277	.294
RWDSI	.080	.086	.141	.028	-.203	.302
EVAL	.082	-.064	.233	.056	-.198	.350
MISSTB	.122	.158	.241	.000	-.247	.117
FREEDA	.002	.002	-.259	-.012	-.254	.013
TWORK	-.282	.419	.128	.014	-.194	.091
PMIL	-.478	-.195	.056	-.055	.113	.146
AGE4	.813	.107	.089	.124	.003	-.015

CORRELATION MATRIX-PREDICTOR VARIABLES (cont)

	AG4XED	NWU	GRPSIZ	GRPSZ2	LAB1	LAB2
AG4XED	1.000	.156	.077	.048	-.028	-.028
NWU		1.000	.269	-.077	-.280	-.034
GRPSIZ			1.000	.694	-.191	.414
GRPSZ2				1.000	-.216	.384
LAB1					1.000	-.471
LAB2						1.000

APPENDIX G

CODING SCHEMES

INDIVIDUAL LEVEL CODING SCHEME

VARIABLE[1]	VALUE	CODE
AGE	Actual years	Actual years
EDCTN	Ph.D. M.S. B.S.	1 2 3
IGHOMO	Mode Otherwise	1 0
GRADE	GS 6,7,8 and 2dLt. GS 9,10 and 1Lt. GS 11,12 and Capt. GS 13 and Maj. GS 14 and Lt.Col. GS 15	1 2 3 4 5 6
TINGRP	Actual years	Actual years
SCIORE	Scientist Engineer	1 0
TSEEXP	Actual years	Actual years
TFEDSE	Actual years	Actual years
NWORKA	Research, Engineering, System Program Office Support, Other	Actual number of work areas
TNOTCH	Actual percent	Actual percent x 100
PROMTG	Actual number per year	Actual number per year
COMWIG	Actual number of contacts per week	Actual number of contacts per week
COMOUT	Actual number of contacts per week	Actual number of contacts per week

(1) The abbreviations used are defined in Table XII.

INDIVIDUAL LEVEL CODING SCHEME (cont)

VARIABLE	VALUE	CODE
COMWGL	Actual number of contacts per week	Actual number of contacts per week
QPRESS	Scale value	1-9
IPRESS	Scale value	1-9
TPRESS	Scale value	1-9
RELPRS	Scale value	1-9
GLPCMP	Scale value	1-9
PARTG	Scale value	1-9
PARTDM	Scale value	1-9
EMPTHY	Scale value	1-9
RWDSQ	Scale value	1-9
RWDSI	Scale value	1-9
EVAL	Scale value	1-9
MISSTB	Scale value	1-9
FREEDA	Scale value	1-9
TWORK	(Predominant category)	
	Support	0
	Development	1
	Research	2
MILCIV	Military	1
	Civilian	0
AGE4	≤29	1
	30-39	2
	40-49	3
	≥50	4

INDIVIDUAL LEVEL CODING SCHEME (cont)

VARIABLE	VALUE	CODE
AG4XED	AGE4(1-4) x EDCTN(1-3)	1-12
EMXCOL	EMPTHY(1-9) x COMWGL(1-9)	1-81
EMXLCP	EMPTHY(1-9) x GLPCMP(1-9)	1-81
EMXPG	EMPTHY(1-9) x PARTG(1-9)	1-81
EMXRWQ	EMPTHY(1-9) x RWDSQ(1-9)	1-81
EMXRWI	EMPTHY(1-9) x RWDSI(1-9)	1-81
EMXEVL	EMPTHY(1-9) x EVAL(1-9)	1-81

GROUP LEVEL CODING SCHEME

VARIABLE (1)	VALUE (2)	CODE (3)
AGE		$\bar{G}$
EDCTN		$\bar{G}$
GHETER	Number of disciplines within the group	1-5
GRADE		$\bar{G}$
TINGRP		$\bar{G}$
PSCI	Ratio of number of scientists to group size	0-1.0
TSEEXP		$\bar{G}$
TFEDSE		$\bar{G}$
NWORKA		$\bar{G}$
TNOTCH		$\bar{G}$
PROMTG		$\bar{G}$
COMWIG		$\bar{G}$
COMOUT		$\bar{G}$
COMWGL		$\bar{G}$
QPRESS		$\bar{G}$
IPRESS		$\bar{G}$
TPRESS		$\bar{G}$
RELPRS		$\bar{G}$

(1) The abbreviations used are defined in Table XXII.
(2) Blank means same value as for individual level.
(3) $\bar{G}$ means group average.

GROUP LEVEL CODING SCHEME (cont)

VARIABLE	VALUE	CODE
GLPCMP		$\bar{G}$
PARTG		$\bar{G}$
PARTDM		$\bar{G}$
EMPTHY		$\bar{G}$
RWDSQ		$\bar{G}$
RWDSI		$\bar{G}$
EVAL		$\bar{G}$
MISSTB		$\bar{G}$
FREEDA		$\bar{G}$
TWORK		Mode
PMIL	Ratio of number of military to group size	0-1.0
AGE4		$\bar{G}$
AG4XED		$\bar{G}$
NWU	Actual number	Actual number
GRPSIZ	Number of scientists/ engineers	Number of scientists/ engineers
GRPSZ2	(GRPSIZ - average GRPSIZ)^2	0-16
LAB1	LAB1 Otherwise	1 0
LAB2	LAB2 Otherwise	1 0

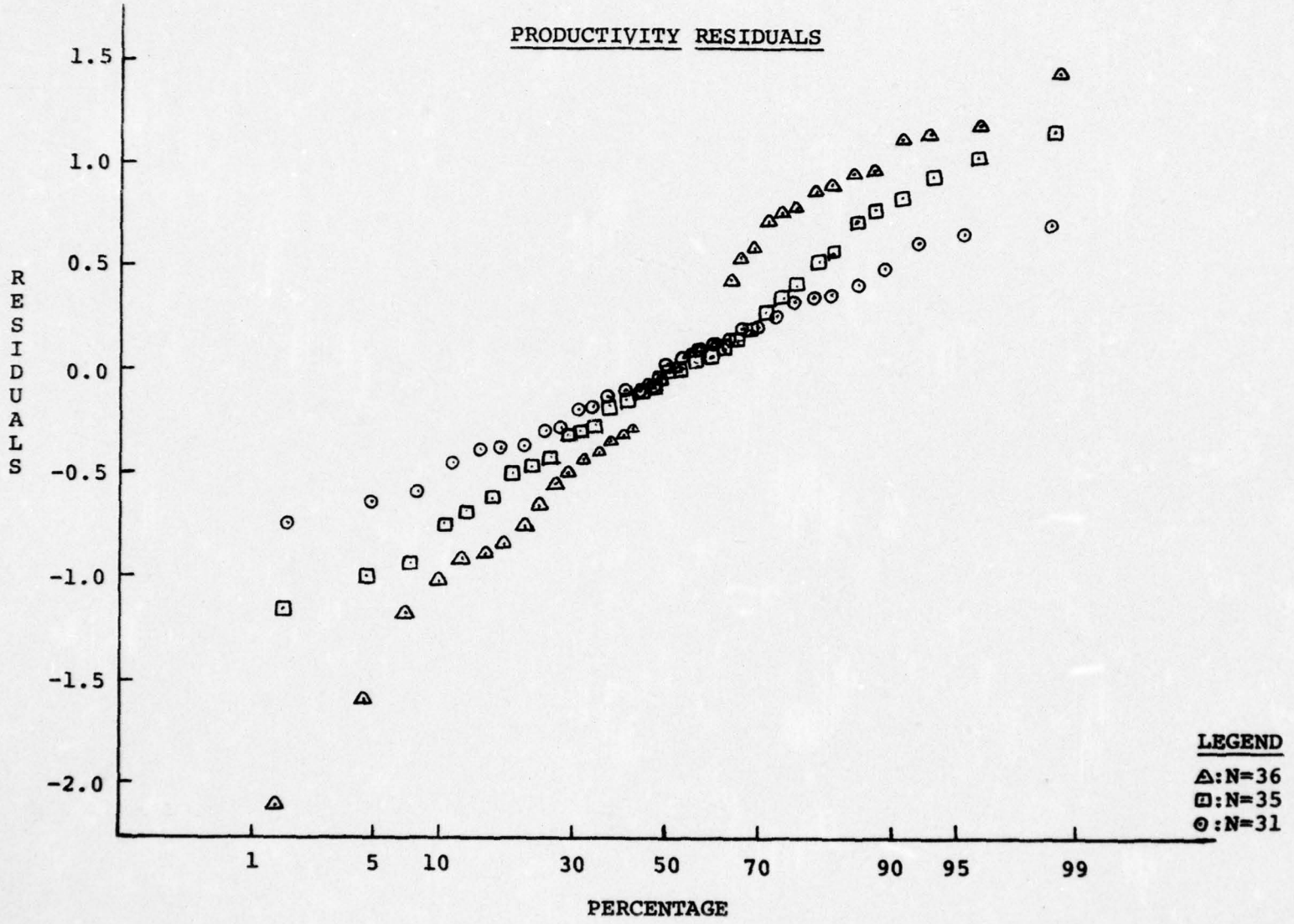
APPENDIX H

COMPUTER PROGRAMS UTILIZED

COMPUTER PROGRAM TITLE	SOURCE
BMD01V - Analysis of Variance for One-Way Design	Dixon (1973)
BMD02R - Stepwise Regression	Dixon (1973)
BMD06D - Description of Strata	Dixon (1973)
CANONA - Canonical Correlation Analysis	Veldman (1967)
NON PAR CORR - Spearman Rank-Order Correlations	Nie,et al. (1975)
PEARSON CORR - Pearson Product- Moment Correlations	Nie,et al. (1975)
ROBUST REGRESSION	Schumaker (RPI)
TWO CHI GOODNESS OF FIT	Schumaker (RPI)

APPENDIX I

NORMAL PROBABILITY PLOTS OF PRODUCTIVITY RESIDUALS FOR N = 36, 35 and 31


PRODUCTIVITY RESIDUALS
RESIDUALS
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
1
5
10
30
50
70
90
95
99
PERCENTAGE
LEGEND
△:N=36
□:N=35
⊙:N=31

VITA

Michael J. Stahl was born on 25 May 1946 in Scranton, Pennsylvania. He graduated from high school in Scranton, Pennsylvania in 1964. He attended the University of Scranton and then the State University of New York at Buffalo, from which he received a Bachelor of Science Degree in Electrical Engineering in 1969. At that time, he was commissioned as a Second Lieutenant in the United States Air Force. He was initially assigned to the Air Force Institute of Technology to study for a Master of Science Degree in Systems Management and was awarded that degree in December 1970. A subsequent assignment placed him as a Systems Program Management Officer on the development of the Fleet Satellite Communications System at the United States Air Force Space and Missile Systems Organization, Los Angeles Air Force Station, California until July, 1973. He began work on a Doctor of Philosophy Degree in Management in September, 1973 at Rensselaer Polytechnic Institute, Troy, New York. That degree was awarded to him in December 1975. He is currently an Instructor in Management in the School of Engineering, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

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Productivity
Research and Development
Organizational variables
Organizational Climate
Creativity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The relationships of organizational variables with innovation and productivity of scientists and engineers in R&D laboratories were explored. Peer ratings of innovation (original and useful output) and productivity (quantity of output) were utilized as criterion. Information was obtained on 154 scientists/engineers in 35 work groups in three Air Force R&D laboratories. Significant relationships found between organizational variables and innovation and productivity included: rewards for innovation, communication on

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technical matters with other scientists/engineers within the work group, and an age-education demographic group of variables. Level of participation in goal setting and group leader's level of empathy were also consistently related to level of productivity.